U.S. Department of Energy
Advanced Scientific Computing Advisory Committee (ASCAC)
Subcommittee on LDRD Review
First Report to the Committee, 11th April 2017

Table of Contents

Executive Summary

The Advanced Scientific Computing Advisory Committee (ASCAC) was given a charge by Director of the Office of Science, C.A. Murray, in May 2016 (Appendix A) to perform a review of the Laboratory Directed Research and Development (LDRD) program across the DOE National Laboratories (Labs). Toward that end, ASCAC convened a Subcommittee, chaired by Dr. Martin Berzins, to conduct the review. The Subcommittee represents its findings in this report, along with supplemental background material gathered by the Subcommittee during the review process.

This Subcommittee (with membership listed in Appendix B), collaborated via telecon over the course of several weeks to develop a process for a detailed review of the DOE LDRD program, paying attention to the points raised in the Charge Letter from Director Murray. We developed a plan to gather information through a series of site visits to four representative Labs, along with a comprehensive review of LDRD Annual Reports and other reports reviewing LDRD. Each Lab was given a charge to prepare their site visit to address a common list of questions, and asked to send in advance any preliminary information, so that the in-person meetings would be able to dive deeper into their LDRD processes and impact. These site-visits took place between January 4th and February 2nd, 2017. Detailed reports on each individual visit were then prepared following a common template to make them more readily comparable. These reports are provided in Appendix D.

In the charge, the Subcommittee was asked to consider the overall impact of LDRD within each Lab, and each Lab's *processes* to

- Determine the funding levels for the LDRD programs,
- Determine Lab-specific goals and allocate resources among the goals,
- Select specific projects, and
- Evaluate the success and impact of the LDRD program against Lab-specific goals and the overall objectives of the LDRD program over a ten-year period.

The Subcommittee was mindful during the review of the objectives of the DOE LDRD program, which are well documented, and were restated in the charge letter. Namely these objectives are to

- Maintain the scientific and technical vitality of the Labs,
- Enhance the Labs' abilities to address current and future DOE and National Nuclear Security Administration (NNSA) missions,
- Foster creativity and stimulate exploration of forefront science and technology,
- Serve as a proving ground for new concepts in R&D, and
- Support high-risk, potentially high-value R&D.

The Subcommittee's response to its charge to ASCAC is summarized here, following the structure of the points of the charge.

What are the processes to determine the funding levels for the LDRD programs?

Operating within the Congressional-mandated 6% limit in general and of not less than 5% and not more than 7% for NNSA Labs doing national security work from 2016, the process to determine the Lab funding level balances the strategic needs of the Lab against the overhead burden on other Lab funding. Differences in funding levels reflect varying Lab missions and the need to balance exploratory and strategic research against blue-sky high-risk research and fellowships to ensure recruitment. The committee observed that considerable care was taken in this process to address the strategic and operational needs of the Lab within the bounds of the funding limits mandated by Congress.

What are the processes to determine Lab-specific goals and allocate resources among the goals?

Each Lab has a slightly different process for goal setting. A common theme is a high level strategic view taken by senior management to define the goals and areas for projects to address. This very clearly structured process aligns the majority of LDRD activities with Lab goals while leaving room for ground-up blue-sky funding and Lab fellowships to introduce novel approaches that will eventually contribute to and help shape evolving Lab priorities.

What are the processes to select specific projects?

Multi-level procedures with the expended effort being proportional to the likelihood of funding and with feedback levels are used in a constructive approach to project selection. White papers leading to full papers and presentations are typically used in conjunction with mentoring to reduce wasted effort. The processes appear to be fair and well-managed with a strong developmental aspect that is both noteworthy and efficient in the long term.

What are the processes to evaluate the success and impact of the LDRD program against Lab-specific goals and the overall objectives of the LDRD program over a ten-year period?

The procedures for evaluating success and impact include a high-level federal aspect and a detailed laboratory aspect with multiple levels of evaluation at different times. This can include external expert review and, for some of the Labs, exit plans and post-project assessment over several years (typically two to five), following the end of the project.

What is the impact of the LDRD program?

The Subcommittee observed the considerable and long-lasting impact of LDRD projects at a number of different levels. These levels range from standard metrics such as publications and patents, through to spin-off companies and follow-on DOE programs that build upon the research led by LDRD. The committee observed that the use of LDRD to provide fellowships for new hires and blue-sky research had a profound impact on the quality of both the research undertaken and the caliber of the Lab staff undertaking it. The LDRD program has allowed Labs to better accomplish their mission as well as allowing them to respond rapidly to emerging issues and to allow the US to remain at the forefront of technology.

Observations, Recommendations and Best Practices

1. LDRD must be maintained at its present level to attract and retain the high-quality workforce DOE Labs currently enjoy. The program provides a way to offer new and existing staff the opportunity to explore new challenges, while also showcasing the research strengths of the Labs. The committee is convinced that LDRD program is vital to maintaining the workforce capability which will allow the Labs to meet current mission goals, and be prepared for future national challenges.

2. LDRD must be maintained at its present level as it is essential to maintaining the laboratory Science Technology and Engineering (ST&E) base both now and looking to the future. It allows the Labs to conduct the longer-term fundamental research aimed at developing the new ideas and techniques that experience demonstrates will be key to addressing future energy and national security challenges.

3. All DOE Labs should introduce processes, similar to those already in use at some Labs, to document and highlight the longer-term (> 5 year) impact of LDRD as a national asset. For example, a consistent process to track and understand the impact of projects so that it is clear which LDRD projects led subsequent beneficial activities.

4. There should be a similar degree of informal LDRD coordination between non-NNSA Labs as presently exists between the NNSA labs. This will likely help increase the impact of LDRD across the Lab system and beyond.

5. Some LDRD best practices at the Labs might be deployed more broadly. These could include designating a “lead reviewer” for all proposals, with duties beyond simply reviewing the proposal; the designation of “LDRD Points of Contact” within the major laboratory directorates to play a critical role in ensuring program integration in all areas of the LDRD program; the requirement that every proposal develop an exit strategy to help maximize impact; and a requirement for a clear statement of how every proposal benefits DOE in the annual reports.

Conclusions of the Subcommittee

- The overall view of the Subcommittee is that the LDRD Program provides a unique combination of high-level laboratory-driven strategic research and “blue sky”, investigator driven, fundamental research based upon individual innovation in a framework that has constructive federal, laboratory and external oversight at multiple levels.
- Overall, the LDRD program appears to be very well run and monitored, in accordance with the intent of the DOE program, and with processes that couple innovation at the

Laboratory and individual scientist level with the Nation’s anticipated future security, energy, science and engineering needs.

- Both the level of funding and the LDRD funding mechanisms are appropriate and necessary for the Labs to continue to perform at their present high levels of R&D for the DOE.
- A more systematic approach to monitoring the long-term impact of the LDRD program at the Labs would make it easier for the great successes of the program to be more widely understood and appreciated.

Historical Background

The historical background of the LDRD program is well described in numerous reports (for example, the Final Report of Commission to Review the Effectiveness of the National Energy Laboratories, Volumes 1 and 2, 2015). The origins of the LDRD program go back to the beginnings of the Labs themselves and to the Atomic Energy Act of 1954, as amended (42 U.S.C. 2011 et seq., in Section 31), which directs the Department of Energy (DOE) to ensure the continued conduct of research and development (R&D) and to assist in the acquisition of an ever-expanding body of theoretical and practical knowledge in the fields of energy, its production, uses, handling, and effects. The stewardship of this mission, started with the Atomic Energy Commission (AEC), later moved to the Energy Research and Development Administration, (ERDA) and finally to DOE. From the beginning, the AEC recognized that leaving a certain amount of resources to be allocated for R&D to the Lab Director’s discretion made it possible to maintain the Labs’ intellectual vitality, their ability to respond immediately to developments at the cutting edge of science and technology, and their ability to retain the best scientific, technological, and managerial talent.

Following from this start in 1954, the discretionary R&D program was formalized as the Exploratory Research and Development Program in 1985 and in 1991 became the Laboratory Directed Research and Development (LDRD). Together with analogous programs at the Department's nuclear weapons production plants (Plant Directed Research and Development (PDRD)) and the Nevada National Security Site (NNSS) (Site Directed Research and Development (SDRD)), LDRD is an active part of the DOE mission to promote scientific and technical (S&T) innovation that advances the economic, energy, and national security of the United States (US).

The level of funding of LDRD is governed by *S*ection 309 of Division D of the Energy and Water Development Appropriation Act, 2014, (Public Law 113-76) and is limited to a maximum of six percent of a Lab’s total operating and capital equipment budgets for each year, including non-DOE funded work. NNSA labs have a slightly higher level of 7% from 2106 for Labs doing national security work as a result of the National Defense Authorization Act. For reference, the aggregate funding level for 2015 was 4.15 percent of the certified total cost base of the National Lab program.

DOE Order 413.2C, titled: “Laboratory Directed Research and Development” governs the LDRD programs at the DOE National Labs, while supporting the Labs’ statutory authority to pursue innovative, self-selected projects in support of the DOE mission. DOE's LDRD policy includes the need to obtain prior approval to ensure that each project complies with Departmental policy, as well as annual planning and reporting requirements. Program and peer reviews (both internal and external) are conducted systematically to ensure the investments reflect highly innovative research projects of the highest quality.

As mentioned in the Executive Summary, DOE Order 413.2C defines the five objectives of LDRD as:

1. Maintain the scientific and technical vitality of the laboratories;
2. Enhance the laboratories’ ability to address current and future DOE missions;
3. Foster creativity and stimulate exploration of forefront science and technology;
4. Serve as a proving ground for new concepts in research and development;
5. Support high-risk, potentially high-value research and development.

Previous Reviews of LDRD

There have been many careful reviews undertaken throughout LDRD’s history, and these have focused on strategic, technical and financial aspects of the program. For example, each National Lab conducted an internal review of their LDRD projects from FY 2015 to determine the relevance of those projects to the missions of the various Lab stakeholders who provided funds for LDRD in that year [REF 2 Volume].

The earliest available GAO report in 2001 (GAO-01-927, 2001) addresses the structure funding and performance indicators for the LDRD program and notes that some relatively minor changes in performance indicators would provide a more consistent reporting framework. As subsequent GAO Report (GAO-04-489, 2004) describes the LDRD funding structure from 1998 to 2003, though without analyzing the impact of the program. As documented in the 2004 Report on LDRD, the GAO found that the program met statutory requirements and that Labs clearly communicated the costs of LDRD to customers. The report of a recent audit of Lawrence Livermore's LDRD Program (other Labs were not audited) by DOE’s Inspector General (DOE Office of Inspector General, 2014) stated that “…*nothing came to [the IG’s] attention to indicate that controls were not in place over initial LDRD project approval and subsequent project management*…”, and made no recommendations regarding the program’s management. Interviewees at DOE headquarters and Labs report that the current LDRD program is well-managed and supports DOE and other Federal agency missions and that existing oversight mechanisms ensure compliance of LDRD with Department regulation.

The primary finding of a 2015 Congressional Commission (Commission to Review the Effectiveness of the National Energy Laboratories, 2015) was that LDRD is a key investment in the future. The purposes of LDRD are clear and crucial: to recruit, develop, and retain a creative workforce and to produce the innovative ideas vital to each Lab's ability to produce the best scientific and future mission work. For these reasons, the Commission strongly endorsed the need for LDRD programs, both now and into the future. Some of the detailed findings of the 2015 Commission are:

- LDRD has a long history of support and accomplishments, dating back to 1954 when it was first authorized by the Congress. Formal requirements for LDRD projects, external review, and DOE oversight ensure that projects are selected competitively and that they explore innovative, new areas of research not already covered by existing programs.
- LDRD is a resource for supporting cutting edge exploratory research prior to the time that a research program is identified and developed by DOE. Multiple LDRD projects at various laboratories may be funded in the same topic area as a means of exploring different potential paths for an ultimate program in the field. These small, early stage projects provide valuable insights for the peer-review, strategic assessments by DOE as part of the program planning process.
- LDRD is an important recruitment and retention tool for the National Laboratories. This is especially critical at the NNSA laboratories, which must attract new staff into the laboratories to maintain a highly-trained workforce to support the NNSA's nuclear weapons and national security missions.

The GAO Report of 2016 (GAO-16-486R, 2016) explored the funding limits on NNSA's LDRD program, and compared the limits between their Labs and similar programs at other DOE and DOD Labs. This report also considered the number of personnel supported by LDRD funding at NNSA Labs and the number of those who were supported by LDRD funding for the majority of their time (> 50% effort). The report did not make any recommendations for changes.
Having drawn on these reports, and based upon its own knowledge of the LDRD program the Subcommittee developed a framework for our response to the charge given.

Laboratory Visits

In the charge letter to the committee Dr Murray (see Appendix A) asked that four labs be visited. One lab should be an NNSA lab, one should be an Office of Science Lab and one of the others should be an applied energy lab. Accordingly, four Labs were picked as examples of the type of LDRD work undertaken. LBNL is an Office of Science lab, LLNL is an NNSA lab. ORNL is a broad lab with a mixture of work and NREL is an applied energy lab.

The Subcommittee met via teleconference several times from September through November 2016 in preparation to address our charge. Through that collaborative effort, the Subcommittee developed a uniform list of requests to pass forward to each of the Labs being visited, to ensure that they would each get the same guidance. This process helped ensure that the Subcommittee would be able to get consistent information from each of the Labs, and that the site visit would be focused to specifically address the charge. The charge letter to the Labs is included in

Appendix C. This document did not specify a detailed agenda but did ask for precise responses to our charge questions, meeting junior PIs, a poster session and discussions with the LDRD site office leads etc. The timings of the visits are given in Appendix C. Appendix D describes the individual lab visits.

While the visits varied in format the outline was similar in each case. Each visit started with the Lab Director presenting an over view of the Lab and their view of the importance of LDRD to the lab. The visits included the Lab Associate Directors and other senior leadership team members (and in one case the Lab Director) being present for most of the day. The poster sessions with LDRD researchers and the panel session at LBNL with LDRD researchers were particularly important in terms of understanding workforce issues. Three of the lab visits were accomplished in one day. In the case of the NNSA lab, LLNL, as cleared Subcommittee members were given a briefing on the classified side of LDRD, the visit extended to the morning of the next day. The Labs provided the Subcommittee with the slides of their presentations and with any follow up clarification that the Subcommittee required.

How LDRD Works Today

The LDRD program is tasked with meeting the five goals listed above, ensuring the capacity and vitality of the national lab system. Taken in whole, it comprises 4.15% of the Lab cost base (FY2015). As noted earlier, the Congressionally mandated cap on LDRD budgets has varied over the years. With the exception of the Jefferson Lab and Fermi Lab, the fraction of the Lab budgets that are devoted to LDRD varies from ~1.03% to ~ 5.9% today (based on FY 16 budgets). The NNSA Labs tend to devote larger fractions to LDRD than do the basic science labs.

Currently there are about 1700 LDRD projects/year with an average budget of $300k/project. The Labs each use LDRD to advance their missions and structure project size to meet specific goals. For example, strategic initiatives generally receive larger budgets than do exploratory projects. Most LDRD projects involve early career researchers at some level, which aids in sustaining the Labs' scientific workforce.

All Labs invoke structured processes to set the strategic goals of their LDRD programs. The processes for mapping the LDRD program onto the goals of Labs and the DOE mission are an inherent part of the strategic planning within each lab, to ensure that all directorate activities are aligned, including and especially the LDRD program. Since all Labs operate on a fiscal year, their strategic planning schedules are similar. These processes are effective as will be shown below in addressing the charge.

The topical areas of emphasis that result from the strategic planning processes are specific to the purpose and scientific strengths of each Lab. In each case, they are appropriate for guiding the research directions of the specific Lab, and communicate the value and contributions that the labs make to the overall DOE mission.

As an example, for LBNL in 2017, the four top Lab strategic priorities are:

- Advanced Light Source upgrade
- Exascale for Science
- Biocampus
- Infrastructure renewal

And their six strategic initiatives identified for the 2017 LDRD program are:

- Next Generation of Scientists
- Microbes to Biomes
- Electron Microscopy
- Water-Energy Nexus
- Beyond Moore's Law
- Data Analytics for Science

Similarly, for LLNL in 2017, the strategic initiatives for LDRD funding support the Lab's mission to sustain its leadership in National Security, as well as being responsive to a changing world. Those goals include:

- Stockpile Stewardship Science
- Cyber Security, Space, and Intelligence
- Energy and Climate Security
- Chemical and Biological Security
- Inertial Fusion Science and Technology

The differences between the strategic initiatives of LBNL and LLNL and the fact that both NNSA and SC Labs fit within the LDRD program illustrates how LDRD supports the differing missions of the individual Labs within a single framework, across various types of Labs.

To achieve the respective strategic goals, the Labs invoke several tiers of support: larger projects aimed at evolving new research directions for the Lab; mid sized projects for explorative research that seeds new ideas and supports emerging leaders; projects that support recruitment, retention and anticipated DOE calls for proposals.

The Lab directors are ultimately responsible for the overall execution and management performance of the LDRD program. The LDRD programs are managed by a combination of Deputy and Associate Directors. Associate Lab Directors (ALDs) are involved in all stages of the program: determining strategic directions, review and selections of projects, mentoring and support during the projects, and oversight of the research and outcomes.

As an example, the process that NREL utilizes to determine the focus of the LDRD program is described in detail in Figure 1 below and in the next section. The figure illustrates the multi-level approach used to both make the initial decisions and to monitor the projects. The process is driven by the leadership retreat in February where ALDs present priorities, and proceeds in stages with reviews and review panels until new projects begin at the start of the fiscal year. At the same time existing projects are monitored on a quarterly basis and at their end.

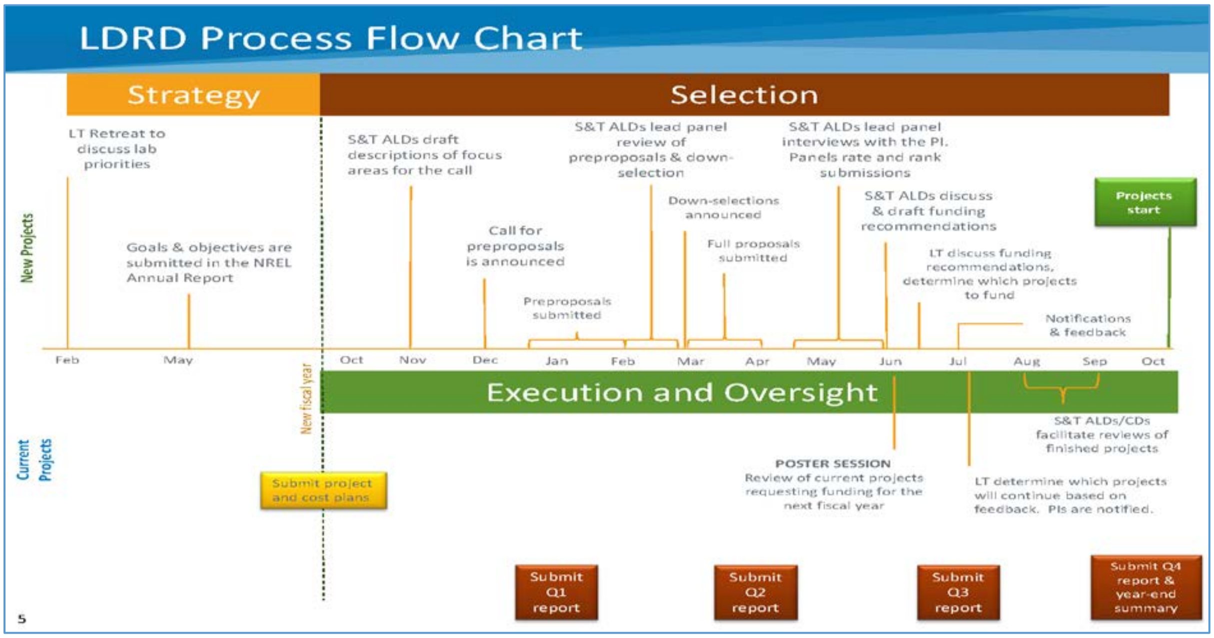


Figure 1 NREL LDRD Selection Strategy and Oversight Summary

The processes for determining research directions at each of the Labs exhibit similarities since they are embedded in the DOE-wide Lab planning processes, which have evolved consistently over the years. The Labs begin with a leadership planning exercise such as a retreat or extended staff meetings. Mechanisms of obtaining input from the directorates are robust, including preproposal evaluation processes, young scientist mentoring sessions, etc. Formal and informal interactions are supported to develop programs across and between directorates.

The selection processes all consider: quality of science, consistency with Lab mission and capability of the Lab, the extent to which a DOE need is addressed, and realistic potential for becoming a large programmatic direction for DOE. All Labs maintain a proposal evaluation process to make decisions about LDRD research. Some invoke a “white-paper” or “pre-proposal” stage to increase process efficiency. The selection processes involve evaluation teams, with internal reviewers, and, where appropriate, external experts drawn from the community. Finalists make presentations to leadership review panels, which then make funding decisions taking everything into balance.

The projects once funded are regularly monitored and care is taken to ensure that they meet their technical and are on target with their spending. When the projects are completed there is also an evaluation phase that varies across the labs but involves monitoring of metrics, such as publications, patents for example and follow on plans.

In addition to Lab oversight, federal oversight also spans the LDRD lifecycle. These processes are described more completely in the following section.

Addressing the Charge

What are the processes to determine the funding levels for the LDRD programs?

The funding process that governs LDRD has two main aspects. The first is the interaction between each laboratory and DOE HQ and the second is the process that takes place inside the lab itself. As must be the case Federal oversight spans the entire LDRD lifecycle from the point of view of the funding processes. Broadly speaking DOE NNSA HQ and Field/Site Office federal officials ensure compliance with LDRD DOE Order and that there is uniform department-wide guidance. Prior to the start of the new fiscal year in September, the Labs submit the Lab LDRD funding rate levels and program plans to DOE. If the plans are satisfactory they are approved. This process can incorporate a Lab decision either to keep the LDRD percentage rate constant or to increase the rate, compatible with the maximum allowed. The different rates across the Labs reflect the nature of the different Lab missions. Figure 2 shows this breakdown for the NNSA, SC and other Labs.

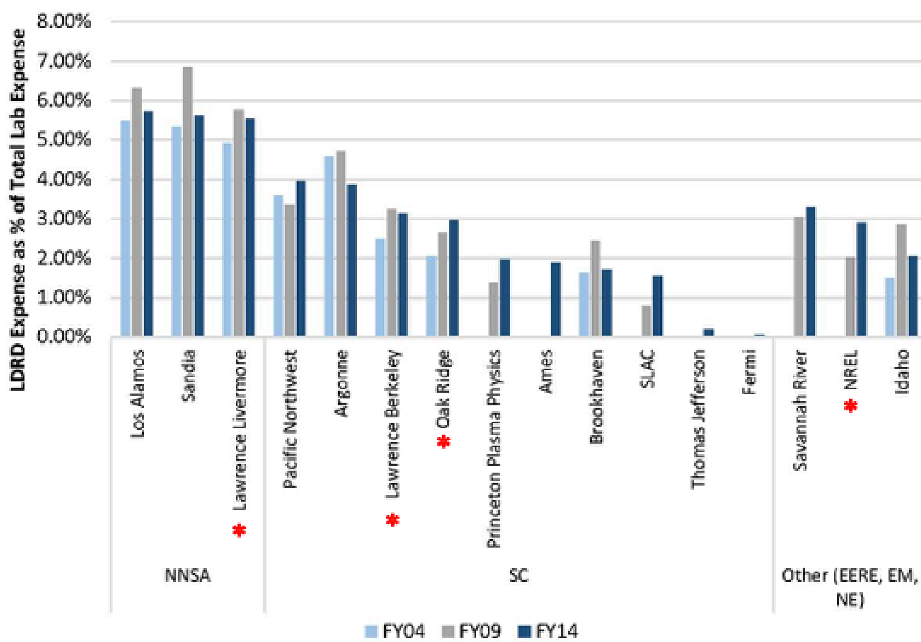


*Figure 2: LDRD funding percentages across Labs; * indicates the Labs visited.*

Each Lab and DOE Field/Site Office meet to review and ensure project for complies with DOE and other policy (relevance to mission, non-duplication of projects). The Field CFO annually reviews LDRD funds accumulation methods and certifies them if they are correct. This is done prior to DOE approval of the LDRD plans and funding rates. DOE HQ also conducts an annual review of each LDRD program for general health, alignment to relevant missions, and effective and efficient execution and evaluation (through discussion and site visits. A description of Federal impact measurement is provided in the impact section below. The level of federal oversight is appropriate for the funding level of LDRD and does not seem to be administratively burdensome.

Regarding the processes in each of the four Labs that the Subcommittee visited, we found that the process for determining the LDRD funding level for the Labs to be similar but not identical. The process typically starts from development of the annual lab plan in January, with senior management - the Lab Director and Deputy Lab Director - taking input from the Associate Lab Directors (ALDs). After approval of the annual lab plan by DOE, the ALDs and senior management develop a set of Lab strategic priorities and focus areas for the Lab's LDRD program. Each Lab classifies their LDRD project portfolio slightly differently but they are all compatible with DOE's goals for the LDRD program as given in the Executive Summary.

We now summarize the processes at each of Labs visited – more detail can be found in the Lab visit reports in Appendix D.

LBNL

- In January of each year, the senior Lab Management at Berkeley, with input from the ALDs and Division Directors, develop the Annual Lab Plan for submission to DOE in May.
- In April/May of each year, the Divisional Spend Plans are used to derive the outyear LDRD distribution base.
- In July/August, as part of Indirect Budget Formulation, the Lab Senior Management develops the preferred level of LDRD funding. In September, just prior to the new fiscal year, both estimates are finalized. The LDRD rate is the result. LBNL chooses to use only about 3% of total Lab funding for the LDRD program (compared to the maximum possible of 6%). This amounts to about $20M each year for the Berkeley LDRD program.
- In September, the Lab Management decides on a set of Lab-wide Strategic Priorities and Initiatives, and then uses a structured planning process that engages staff and leadership over a 24-month cycle.
- The LDRD program plan is submitted to the Lab's site office to request permission for the program funding rate for the following year. The site office coordinates with DOE HQ and funding authorization is then granted.
- In December, the LDRD call for proposals is issued.
- The LDRD program at the Lab divides the projects into three categories: Lab Initiatives; Area Priorities; People. Most LDRD projects at the Lab are assigned to Area Priorities.

LLNL

- Typically, early in each fiscal year, the LDRD office is given a projection for the funds available for the following fiscal year. Based on that projection, a plan for funding in the various LDRD categories is assembled and incorporated into the draft LDRD program plan which is submitted to the NNSA Livermore Site Office by August 15th. The Site Office approves the program plan, which is then executed starting October 1 and updated during the fiscal year as necessary.

- Initially, LDRD resources are distributed as outlined in the LLNL ST&E Investment Strategy report. The ‘science’ and ‘quality’ of the proposed project will ultimately govern LDRD project selection.
- Because LDRD funding is so integral to the success of the ST&E efforts of the Lab, LLNL maximizes (to the level approved by Congress) the funds that are available for LDRD investments. The funds available for LDRD projects are therefore typically around 90% of the maximum available based on the congressional limit.
- The institutional LDRD funding level is discussed with, and ultimately approved by, the DOE/NNSA site office. The site office also reviews all proposed projects for alignment with mission areas and compliance with all DOE orders.
- LLNL has found that their five LDRD program goals are best achieved if resources are divided into four categories: Strategic Initiative (SI) projects; Exploratory Research (ER) projects; Lab-Wide Competition projects (LW); Feasibility Study projects (FP). The bulk of LDRD funding goes to ER and SI projects.

ORNL

- The strategic planning process at ORNL starts with DOE Lab Plan and the DOE Strategic Plan. The development of an Annual Lab Agenda then guides the detailed LDRD planning process.
- The Lab business plan is aligned to deliver on this strategy. Senior Lab management has made strategic decision to increase LDRD budget from around 3% to 4%.
- The LDRD Program at the Lab has three main components: Director’s R&D Fund; Seed Money Fund; Named Fellowships.
- For Director’s R&D Fund, Initiative Review Committees (IRCs) provide technical and strategic recommendations.
- The R&D priorities identified support ORNL’s major S&T initiatives. These R&D priorities incorporated in annual Director’s R&D call for proposals and classified as: Cross-cutting; Core; Open.
- After a rigorous selection process starting with Town Hall meetings, the IRCs recommend selected projects to Leadership team. The LDRD Leadership team balances portfolio strategically and financially.
- Deputy Director for S&T reviews proposed LDRD portfolio and submits approved proposals to DOE for final approval.

NREL

- The process for determining the LDRD funding level at NREL starts with Lab Retreat to discuss Lab priorities. The Lab’s senior management believe that the LDRD program strengthens NREL’s Core Capabilities and supports the Lab’s mission.
- Senior Lab management has set the LDRD program to be 4% of NREL’s Operating Budget. The Lab’s Goals and Objectives are submitted to DOE in the NREL annual report along with project and cost plans.
- The S&T ALDs then draft the NREL focus areas for the annual LDRD call. The NREL LDRD project portfolio is characterized in four categories: Transformational Initiatives (multi-

year/multi-projects); Sustaining projects (generally 2 years); Seed projects (less than 1 year); Talent Development – the NREL Director's Fellowship Program.

- The S&T ALDs Lead Panel interviews and rank submissions according to 4 criteria: Uniqueness (30%); Relevance/Impact (35%); Quality (20%); Team Strength (15%)
- The NREL Leadership Team the discuss recommendations and selects projects for funding. After approval by the Leadership Team, the selected LDRD projects are submitted to the DOE for final approval.

Overall the funding processes use by the Labs have many common elements in that funding is assigned to both top-down and bottom-up activities thus proving a good mix between strategic lab direction and individual innovation. In all the Labs multiple levels of decision making are used to ensure that when funding is allocated, it is done so wisely and is subject to extensive peer review.

What are the processes to determine Lab-specific goals and allocate resources among the goals?

Each Lab has a slightly different process for strategic planning and goal setting at the Lab level. In general, the Lab Director and Senior Management Team of each lab conduct a one- to two-year process consisting of: progress review; consideration of new developments in National and DOE priorities; a survey of the needs and opportunities within that context; and then development of near-term and long-term plans and strategies to best leverage the core capabilities of their Lab to meet those needs and explore promising opportunities.

The overall LDRD allocation determination process involves a complicated balance to maximize the program benefit in consideration of overhead charges, and varies across the Labs. The Labs visited each have a deliberate annual review during the budget process to identify the most cost-effective allocation to the LDRD program, up to the Congressionally mandated limit, to maximize the research impact of the funds within DOE.

With each cycle of the Lab strategic planning process, and the annual LDRD allocation determination, the Labs we visited employ several strategies/processes to develop LDRD calls for proposals to align with the Lab and National Priorities. Each Lab varies somewhat, but all include a Senior Leadership process (whether a retreat, a series of meeting, a call for input or a combination of these) to develop specific calls for LDRD proposals. The processes employed depend somewhat on the components of the Lab LDRD program. Among the Labs visited, their examples of LDRD components included:

- Strategic Initiatives
- Exploratory Research Projects
- Laboratory-Wide Competitions
- Feasibility Studies (a.k.a. Seed Funding)
- Named Fellowships

Labs visited provided clear descriptions of their process for alignment with goals and allocations of the LDRD funds for each of their LDRD components.

What are the processes to evaluate and select specific projects?

As with the funding process, and using some of the same mechanisms, the evaluation process has both a high level Federal aspect and a more detailed Lab level aspect. At the Federal level, there is an annual review of each LDRD program for general health, alignment to relevant missions, and effective and efficient execution and evaluation (through discussion and site visits) which provides a high-level evaluation of the program. DOE HQ ensures submission of annual LDRD program reports to the National Nuclear Security Administration (NNSA) and DOE Office of Scientific and Technical Information (OSTI) and makes sure that required performance metrics and project data are submitted for annual report to Congress as well as prepare an annual contractor performance appraisal.

Each of the Labs has rigorous, multi-layered procedures to evaluate LDRD proposals and to assess their progress during the project period, as well as collect metrics of success. The evaluation processes are articulated in the annual request for LDRD proposals at each Lab.

> **Highest level of funding (Strategic Initiatives).** For the highest level, often called strategic initiative proposals, the evaluation processes are the most rigorous. The Labs typically require a pre-proposal or white paper to down select the candidates for detailed review. The review teams are the recognized leaders in ST&E at the laboratory often supplemented by subject matter experts from outside of the lab, e.g., chairs of lab-wide advisory committees. Typically, such proposals cut across many disciplines and missions of the Lab. The full proposals are detailed, requiring not only how the project is aligned with the strategic initiative and the technical methods, but most importantly the potential impact of the project, both short term and long term. The review process always includes oral presentations by the PIs. The proposals are evaluated on a numerical scale, with metrics published in the call for proposals.
>
> **Mid-level funding (i.e. more discipline specific)**. LDRD proposals that are more focused on one discipline or directorate of the Lab typically receive the same level of rigorous review as the "strategic initiatives," except that outside experts are not engaged. Often a pre-proposal is required to down select the candidates for detailed review. The review teams are again the recognized leaders in ST&E at the Lab. The full proposals are typically shorter than those for the highest level, but still require a strong motivation for the research and the technical methods, as well as the potential impact of the project, both short term and longer term. The review process always includes oral presentations by the PIs. The proposals are evaluated on a numerical scale, with metrics published in the call for proposals. At many Labs, proposals not accepted for funding at the "strategic initiative" level are subsequently considered for mid-level funding, where the review is rigorous even if the scope of the project would be more restricted. This category can also

include a general competition, sometimes known as a “lab-wide competition,” open to the best ideas, independent of the needs of any specific discipline.

Seed funds for feasibility projects. All the Labs consider relatively small projects proposed over the course of the fiscal year where relatively small amounts of “seed” funding is requested to test a technical concept to experimental capability that could be the foundation for a future larger scale project. The review of these “seed” projects is rigorous, with technical panels that often include previous recipients of seed funding. Written proposals and oral presentations are reviewed.

Prestigious postdoctoral fellowships. Many of the Labs use LDRD funds to attract the “best and the brightest” postdoctoral scholars to the laboratory. All candidates for these prestigious fellowships submit a comprehensive package of research accomplishments and letters of reference, as well as a detailed proposal for a 2-3-year research project. The fellowship application and the research proposal are reviewed by ST&E leaders and senior managers of the Lab, and the process includes oral presentations.

What are the processes to evaluate the success and impact of the LDRD program against Lab-specific goals and the overall objectives of the LDRD program over a ten-year period?

Evaluation after project funding. All LDRD projects at all the Labs are reviewed at least quarterly to ensure that they are expending funds on the proposed schedule and at least at mid-year to assess the progress towards meeting the proposed milestones and on track for impact post-award. Should any project be found to not meet expectations, the technical staff in the principal directorate and/or the lab’s LDRD office work with the PI to strive towards meeting technical and financial milestones. If milestones are not being met, a project can be terminated prematurely. Multi-year projects are reviewed by subject matter committees before funding for a second (or third) year is awarded. Normally projects do not receive more than 3 years of funding at any laboratory and all projects are expected to spend all their funds awarded for a specific fiscal year in that year.

Reporting outcomes. All LDRD projects at all Labs are required to annually report the progress and products of their efforts. The progress is summarized in the Lab’s annual LDRD report that includes metrics such as publications in peer-reviewed professional journals, invited presentations at national and international venues, and intellectual property.

Long Term Impact. The long-term impact of the LDRD program is evaluated as part of the strategic activities of the different Labs. The meetings and/or whitepapers held/submitted at the beginning of the LDRD cycle typically consider past successes on their way to defining current areas of strategic importance. Many Labs take a long view, often as far out as a decade, to invest in areas where expertise is likely to be required in the future. Thus, it is the feedback loop from current work from an activity that has been chosen that influences future activities. For example, LLNL has an exit strategy for each proposal that identifies the future path forward whether it is further research, helping to define a new DOE program or moving towards licensing of technology or even commercial spin-offs. At a more local level the long-term impact of LDRD projects is also reviewed through the performance reviews of the individuals who undertake the work and its potential follow-on projects.

Assessment of the Impact of LDRD

The Subcommittee observed considerable and long-lasting impact of LDRD projects during their visits to each Lab. Some of this impact is described in each Lab's annual report to Congress. The presentations and supplementary written material that each Lab prepared for our visit provided a more detailed view of the activities that underpin these numbers and emphasized that LDRD programs are aligned toward achieving the five goals of the program that are given in the Executive Summary and in the Historical Background section.

1. ***Maintaining the scientific and technical vitality of the Labs***. A key impact of LDRD that enables vitality is the ability to recruit new staff and nurture existing staff. The LDRD program is used to attract post-doctoral researchers and occasionally more senior scientists with critical new skills to work on unclassified projects that are key for meeting Lab strategic goals. LDRD is essential at National Nuclear Security Administration (NNSA) Labs because of the time required for new staff to obtain security clearances. As an example, LDRD has supported over 55% to 90% of the post-doctoral researchers at LLNL over the past 10 years, and typically, 20% to 40% of post-doctoral researchers convert to LLNL staff positions. As indicated below, it is not only the influx of new technical staff that is enabled by LDRD but also the type of work supported by LDRD that is critical to maintaining laboratory vitality. At a Science Lab like ORNL, Named Fellowships – the Wigner, Weinberg, Householder and Russell programs - are used to attract talented early career staff and today support ~24 fellows. Since 2007, 56% of Wigner Fellows have been retained at ORNL as R&D staff. The LDRD program has also been used at ORNL to make strategic staff hires and since 2005 of 26 such hires there has been a 96% retention. Of the 429 PIs and co-PIs on their FY17 LDRD projects, 46% are early career staff.

2. ***Enhance the Labs' ability to address current and future DOE and NNSA missions.*** LDRD allows the Labs to undertake research that enhances their core capabilities and has the potential for produces paradigm changes in critical areas. Several decades ago, large federal programs provided baseline funding for Labs to maintain and enhance their core capabilities. Unfortunately, much of this funding has either disappeared or been shifted to shorter-term

programmatic efforts. Hence, LDRD is required to conduct fundamental research for developing novel new ideas and techniques that experience has shown will be key to addressing future program needs.

The broad portfolio of work viewed by the Subcommittee provided ample evidence that many LDRD projects initiated to enhance core capabilities have revolutionized the way Labs meet current and anticipated future customer needs. For example, LLNL's advanced manufacturing LDRDs have led to better materials being produced more rapidly and at lower cost for several Lab customers. Likewise, LDRD projects in the Stockpile Stewardship area have enhanced critical skills and led to improved high explosives but also delivered better nondestructive testing and manufacturing techniques applicable to a broad range of customers.

As another example, at LBNL an LDRD project on how microbes function in complex soil systems, led to integrated research across the Earth and Environmental Sciences and Biosciences research areas. This resulted in a new Lab initiative in scaling from Microbes-to-Biomes. As a direct result, the DOE now leads the $10M collaborative, interdisciplinary research component of the national Microbiome initiative. Another example is the role of a 2006 LDRD project that resulted in Berkeley Lab leading one of three DOE Bioenergy research centers. The Berkeley center, known as the DOE Joint BioEnergy Institute (JBEI) has now received $250M in funding from the DOE.

3. ***Foster creativity and stimulate exploration of forefront science and technology*.**

Labs use LDRD for anticipating, innovating and delivering solutions that allow them to remain at the forefront of science and technology. Recognizing that LDRD is a *national* resource, several Labs leverage this funding by encouraging strategic collaborations with universities, industry, and other national Labs. For example, the LLNL SPACE Program serves as a proving ground for new R&D concepts within this mission area that have direct overlap and "dual-use" applicability to core Lab programs (e.g., Stockpile Stewardship). This approach has built credibility with other US government sponsors by demonstrating the utility of Lab innovations and developing an agile, multi-disciplinary staff that can quickly form new teams to support a variety of science and security missions. The network of LDRD projects in the SPACE program are illustrated in Figure 3, which shows how several short projects, including 7 LDRD projects, in a very broad area contributed to the accumulation of knowledge at LLNL. This LDRD portfolio benefits several LLNL core capabilities and provides a good illustration of how LDRD projects combine to help create a world-leading research capability.

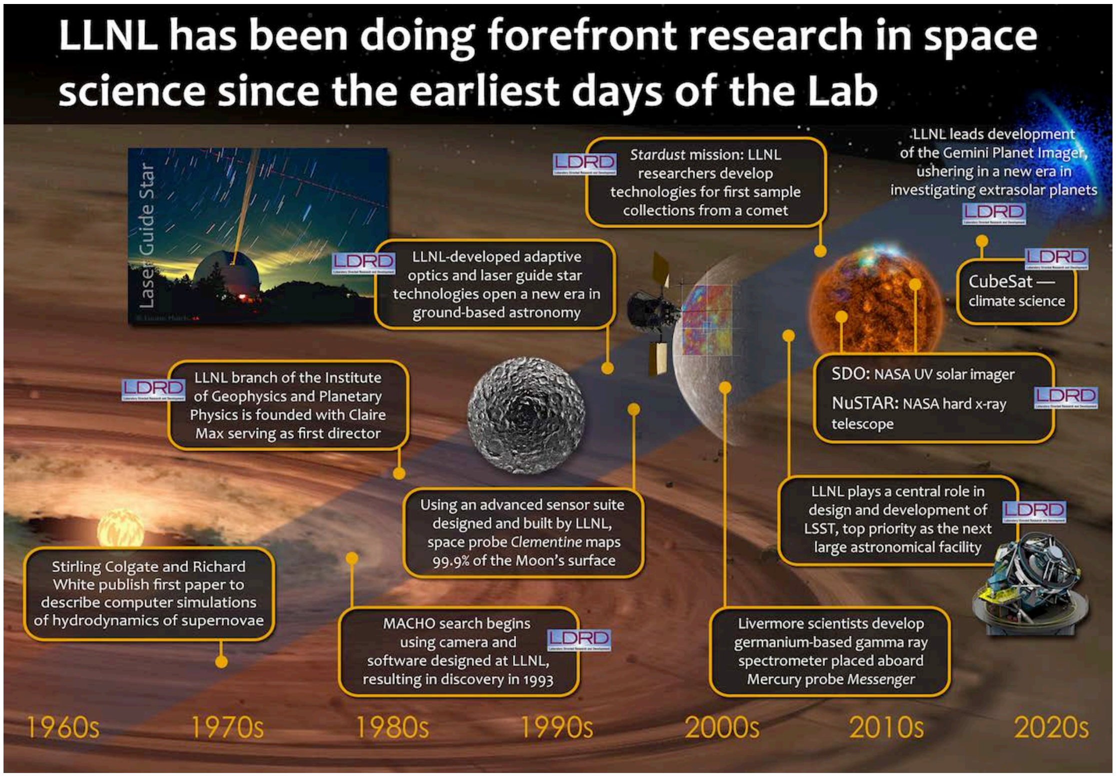


Figure 3: LLNL LDRD Enabled Space Program

LDRD initiatives provide a foundation for many new industries, such as in ORNLs LDRD work enabling large scale Additive Manufacturing for industry, where two LDRD projects led to $50M in DOE funding, 50 publications, 25 invention disclosures and seven patents and helped create additional U.S. jobs and keeping the U.S. competitive in the international arena. Other examples of such LDRD efforts include ORNLs extreme-scale computing program which over a period of eight years has positioned ORNL to be a world leader in high performance computing and to play a major role in the DOE Exascale Computing Project, NREL's Grid Modernization / Energy System Integration project that provided the framework for the Department of Energy's Grid Modernization Laboratory Consortium. LBNL's Camera activities where three LDRD grants introduced an activity that applied novel mathematics to several new Lab areas and awarded a $10M DOE grant to continue this work.

As a final example of the LDRD program stimulating a breakthrough in forefront science and technology, Jennifer Doudna's LBNL LDRD project in 2008 on CRISPR DNA strands has led to what MIT Technology Review called the 'Biggest Biotech Discovery of the Century'. The early work on the LDRD project has resulted in the transformative CRISPR/Cas9 gene editing technology some years later.

4. ***Serve as a proving ground for new concepts in R&D.*** The LDRD program provides the opportunity to explore new ideas and obtain data required to justify and develop large scale programs with major scientific and programmatic impact. At NREL, LDRD research has led to a factor of three improvement in solar cells. At ORNL, research into new approaches for radiation transport has led to a $250M computation and simulation hub (see Figure 4). At NREL, the Subcommittee heard about 12 LDRD projects that have led to over $20 M in follow-on DOE funding.

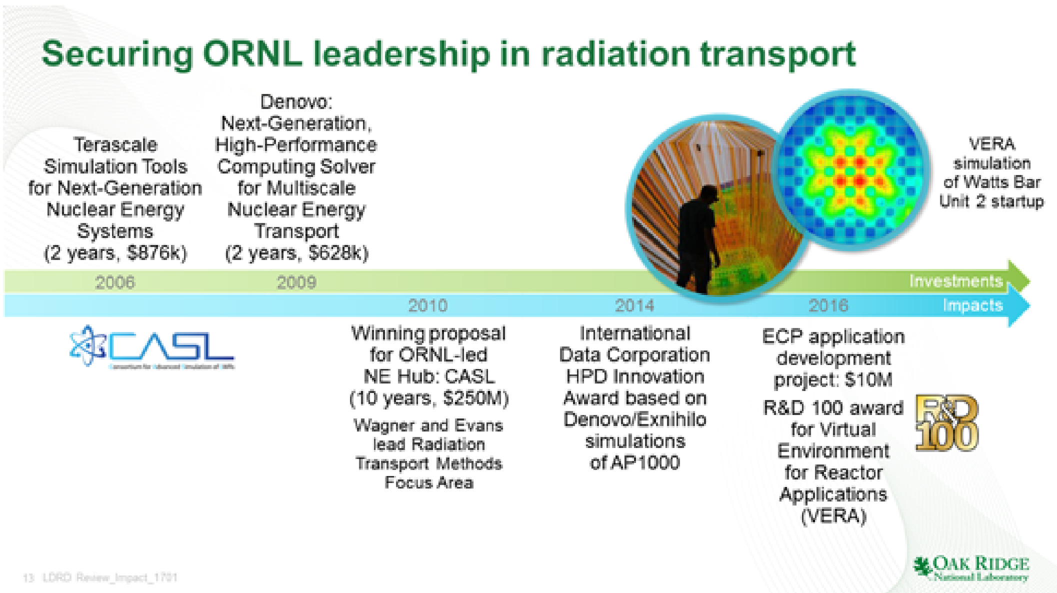


Figure 4:ORNL's Radiation Transport Research Timeline

Although most LDRD funding supports projects to enhance their core competencies and develop new programmatic thrusts that leverage these competencies, each Lab has established a fraction of their resources for 'proof of concept' evaluations. These smaller, short-term efforts determine the feasibility of a technical concept for addressing a mission-relevant challenge. During our visits, we heard of several successful 'proof of concept' LDRD efforts that have been used to maintain the competitiveness of Lab user facilities, such as LLNL's National Ignition Facility, ORNL's Advanced Neutron Source, and LBNL's Advanced Light Source. Even when evaluations found the concept to not be viable, the LDRDs were successful in that a smaller amount of funding precluded establishment of large federal programs that would have been more difficult to terminate.

5. S**upport high-risk, potentially high-value R&D.** The rapid funding process and adaptive nature of LDRD makes risk-taking possible that would be hard to justify in large-scale programs. The exploratory nature of such projects leads to LDRD programs consistently accounting for a high fraction of Lab publications and awards. An example of this is shown in Figure 5, which shows recent and ongoing work at LLNL to understand the impact of LDRD

publications. The figure shows that LDRD publications at LLNL have both a higher impact and more citations than non-LDRD publications at LLNL. Although this facilitates tracking some LDRD metrics, it is important to recognize that some contributions of high-risk/high value LDRDs are more difficult to trace. For example, the LBNL LDRD project investigating Computational Innovations to Measure the Parameters of the Universe allowed the principal investigator to shift his research toward a different direction leading to a non-LDRD DOE project funding that ultimately led to a Nobel Prize for the PI Saul Perlmutter in 2011.

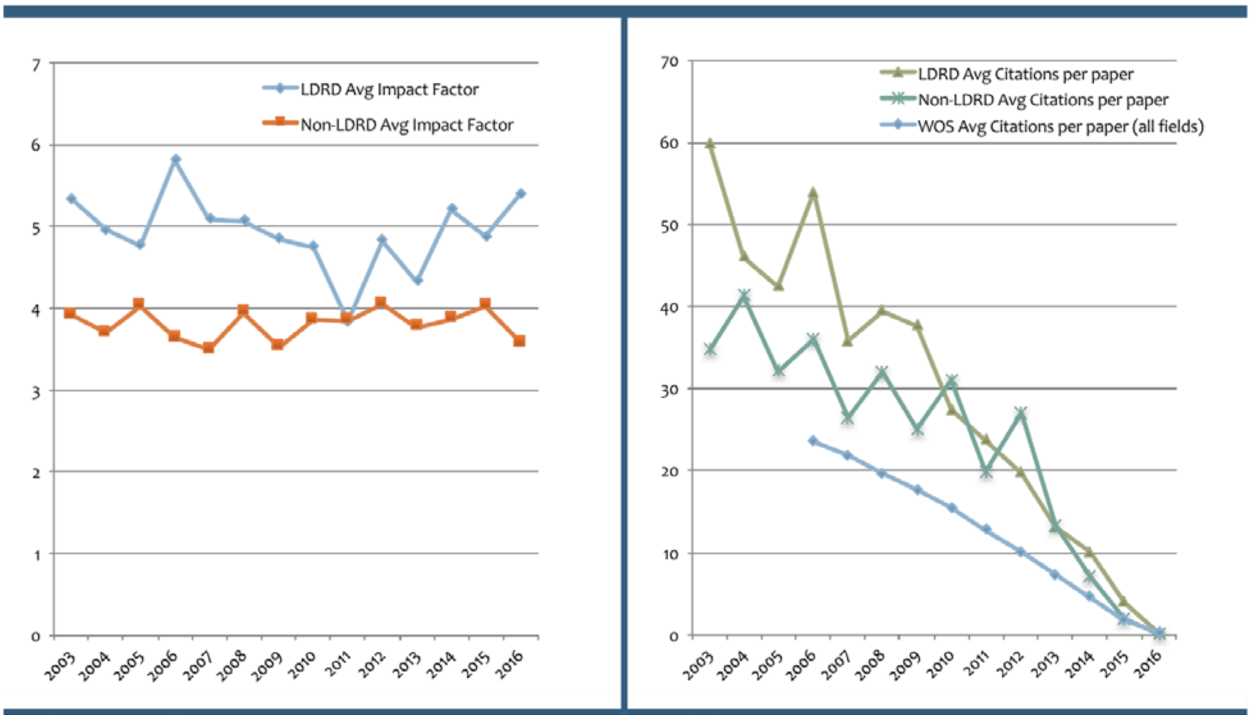


Figure 5: LLNL LDRD vs non LDRD Publications Comparison

It was clear to the Subcommittee that the LDRD program is an essential and integral resource for the Labs and the nation. Each Lab stressed their efforts to maximize the impact of this precious resource. Labs have established processes to ensure that the projects are wisely selected and reviewed, at least, on an annual basis. Principal investigators for LDRD projects are appropriately mentored to minimize the potential for failure and ensure that results are utilized by the broader scientific community.

Labs demonstrate the impact of LDRD by tracking metrics related to the science (e.g., publications, citations, patents, copyrights, and awards), financial returns (e.g., new program funding, royalty income, etc.), strategic collaborations (students, CRADAs, MOUs, etc.) and workforce development (e.g., strategic hires, early-career hires, post-doctoral researchers, staff retention, staff development, etc.). To gain a more complete understanding of the impact of their LDRD program, efforts are underway by several Labs to extend the duration that these metrics are tracked (e.g., to collect information beyond the end of the project for five to ten years).

The longer-term, and perhaps more significant, impact of LDRD spans beyond these 'easy-to-track' metrics. As discussed above, LDRD fosters creativity within Lab staff, providing researchers the opportunity to explore ideas and obtain data required to justify the need for larger, established government-sponsored R&D programs. Additional examples can be found in the appendices of this report that document how LDRD efforts have allowed Labs to better accomplish their mission, as well as rapidly respond to emerging issues and allow the U.S. to remain at the forefront of technology. Examples are also provided that illustrate how LDRD has provided a foundation for many new U.S. industries, which ultimately lead to additional U.S. jobs or were required to keep the U.S. competitive in the international arena.

Consolidated Assessment

Here we provide an overarching assessment summarizing the Subcommittee's observations and recommendations as they relate to the charge to ASCAC. This assessment is based on the materials provided by the various Labs, our site-visits to four Labs, and a comprehensive review of Annual Reports to Congress.
In what follows, we first provide a summary of the Subcommittee's response to those charge questions described in detail above, as well as recommendations and observations

Summary of Subcommittee Charge Responses:

1. **What are the processes to determine the funding levels for the LDRD programs?**

The overall funding process that governs LDRD is determined by senior management at each Lab and by DOE HQ, subject to the requirement that the overall LDRD percentage not exceed the appropriate congressional limit. This actual LDRD percentage for each Lab is chosen by balancing the strategic needs of the Lab against the extra burden imposed by the limit on those programs funding the Lab. Within each Lab that the Subcommittee visited, the process for determining the LDRD funding level for the Labs was found to be similar but not identical, reflecting the differences in their individual missions. Within each Lab, the LDRD funding is usually assigned to four different types of program. These are typically (i) strategic activities in new areas; (ii) exploratory research in areas of Lab expertise; (iii) blue skies research; and (iv) fellowships for recent/new hires. While details vary, the first two activities typically involve the majority (> 75% of the LDRD funds. In all cases, the Subcommittee observed that considerable care was taken to ensure that these allocations reflect and reinforce the Laboratory mission. Overall the local LDRD offices are thoughtful stewards of the DOE LDRD Program.

2. What are the processes to determine Lab-specific goals and allocate resources among the goals?

Each Lab has a slightly different process for strategic planning and goal setting. In general, the Lab Director and Senior Management Team conduct a one to two-year process consisting of: progress review; consideration of new developments in national and DOE priorities; a survey of the needs and opportunities within that context; and then development of near-term and long-term plans and strategies to best leverage the core capabilities of their Lab to meet those needs and to explore promising opportunities. The overall LDRD allocation determination process is a complicated balancing act intended to maximize the program benefit while considering the burden of overhead charges; and this process varies across the Labs. Each of the Labs visited have an annual review during the budget process to identify the most cost-effective division of funds within the LDRD program to maximize the research impact of the funds. It was clear to the Subcommittee that the processes for mapping the LDRD program onto the goals of each Lab are an inherent part of the strategic planning of that Lab. This well-structured process ensures that all the divisional activities are aligned with the LDRD program. At the same time the more fundamental components of the LDRD program can introduce novel ideas that complement the strategic initiatives.

3. What are the processes to select specific projects?

Selection of projects follows standard procedures in that whitepapers with some leading to full proposals are used in evaluation procedures to select projects. The Subcommittee noted many very constructive aspects of the LDRD processes, namely the filtering, mentoring, feedback and transparency of the process to help ensure that proposer's time is spent as productively as possible. These individual processes operate on multiple levels with checks balances and feedback at every stage. The selection processes involve evaluation teams, with internal reviewers, and, where appropriate, external experts drawn from the community. Finalists make presentations to leadership review panels, which then make balanced funding decisions taking a Lab-wide view. The processes are well-managed, appropriate and seemed very fair and transparent as far as the Subcommittee could ascertain.

4. What are the processes to evaluate the success and impact of the LDRD program against Lab-specific goals and the overall objectives of the LDRD program over a ten-year period?

The processes to evaluate the LDRD at the Labs have both a high-level Federal aspect and a more detailed Lab specific aspect, with multiple levels of evaluation including the use of external experts. At the Federal level, there is an annual review of each LDRD program for general health, alignment to relevant missions, and effective and efficient execution (through discussion and site visits). All LDRD projects in each of the Labs visited are reviewed at least quarterly to ensure that they are expending funds on the proposed schedule, and at least at mid-year to assess the progress towards meeting the proposed milestones and impact. Projects not on target to meet milestones are first given coaching and assistance, but may also be terminated if milestones are not met.

Progress towards goals is summarized in the Lab's annual LDRD report that includes metrics such as publications in peer-reviewed professional journals, invited presentations at national and international venues, and intellectual property. Some Labs track the impact of LDRD and outcomes such as publications, patents etc over a long period of time after the award. Attention is often given to following the impact of LDRD funding in areas of Lab strategic importance. The Subcommittee observed many instances of successful and long standing impact for LDRD, but noted that a consistent approach for tracking both LDRD research publications and relationships between LDRD projects does not yet exist. Planned efforts by LLNL to enhance existing multi-year processes for collecting metrics associated with LDRD programs should better allow them to monitor the long-term impact of LDRDs and demonstrate their success. LLNL should discuss these efforts with the other DOE Labs. The management tools used at ORNL for project tracking are also constitute best-practice and are being shared with the broader LDRD community. ORNL is continuing to innovate in this area by investigating new tools for data analysis that will assist in LDRD portfolio analysis going forward. As another example, at LBNL, although there are some very impressive examples of long-term impact of LDRD projects, it is not clear how systematically these are collected.

5. LDRD Impact

The Subcommittee observed the considerable and long-lasting impact of LDRD during our visits to each Lab. The Labs demonstrated the impact of LDRD by tracking metrics related to the science (e.g., publications, citations, patents, copyrights, and awards), financial returns (e.g., new program funding, royalty income, etc.), strategic collaborations (students, CRADAs, MOUs, etc.) and workforce development (e.g., strategic hires, early-career hires, post-doctoral researchers, staff retention, staff development, etc.). The presentations and supplementary written material that each Lab prepared provided a more detailed view of the activities that underpin these numbers and emphasized that the impact of LDRD programs is aligned with the five goals of the LDRD program:

5.1 Maintaining the scientific and technical vitality of the Labs. The LDRD process helps to maintain the scientific and technical vitality of the Labs by ensuring a breadth of research and helping with recruitment of the DOE workforce of the future. The Subcommittee was impressed with the outstanding research expertise of the LDRD recruited researchers it met on its visits to the four Labs;

5.2 Enhance the ability of the Labs to address current and future DOE and National Nuclear Security Administration (NNSA) mission**s.** LDRD plays a vital role by making significant investments in new R&D activities, a mechanism that has been shown to help DOE develop its future programs. The LDRD program both supports the key core competencies required for the DOE mission, and identifies promising new programmatic thrusts that enhance the Labs' ability to address current and future DOE needs. This was demonstrated to the Subcommittee at all the Labs it visited;

5.3 Foster creativity and stimulates exploration at the forefront of science and technology. Strategic management of LDRD enables the Labs to remain first-rate scientific institutions that are capable of quickly and effectively responding to complex national security challenges. This approach allows the Labs to "skate where the puck is going" and push the boundaries at the leading edge of science and technology. The Subcommittee saw compelling examples of how the leading edge of science and technology was advanced by the Labs over the last decade or more, through previous far-sighted and long-term LDRD research;

5.4 Serves a critical role as a proving ground for new concepts in R&D. New ideas developed through LDRD as a proof of concept are developed in broad science-based activities, mission critical national security initiatives or are further developed through appropriate commercial exploitation. The Subcommittee observed numerous instances of how LDRD results had generated new concepts in R&D both in DOE and through new industrial ventures that grew out of DOE;

5.5 Support high-risk R&D, with potentially very high-value returns. LDRD is used to conduct the longer-term fundamental research aimed at developing novel ideas and techniques that experience demonstrates will be key to addressing future national security challenges. The LDRD portfolios also devotes a fraction of resources (through Lab-wide programs) to individual investigator-driven pursuit of the best technical ideas in any area. There is also a healthy culture that accepts high risk, high-reward research, while recognizing that some LDRD projects, although interesting in research terms, may not be worthy of further DOE investment.

The longer-term, and perhaps more significant, impact of LDRD often spans beyond standard, metrics, such as publications. LDRD fosters creativity within Lab staff, providing researchers the opportunity to explore ideas and obtain data required to justify and develop large-scale programs with major scientific and programmatic impact. The LDRD program has allowed Labs to better accomplish their mission, as well as rapidly respond to emerging issues and allow the U.S. to remain at the forefront of technology.

Recommendations

1. LDRD is essential to attract and retain a high-quality workforce, as it provides new challenges that attracts new scientists and staff, while showcasing the research strengths of the Labs. The Subcommittee was shown through its study that the LDRD program is vital to maintaining the ability of the Labs to fulfill their missions, and to continue doing so into the future by maintaining their workforce.

2. LDRD must be maintained at its present level as it is essential to maintaining the Lab Science Technology and Engineering (ST&E) base both now and looking to the future. It allows the Labs to conduct the longer-term fundamental research aimed at developing the new ideas and techniques that experience demonstrates will be key to addressing future energy and national security challenges.

3. All DOE Labs should introduce processes, like those already in use at some Labs, that highlight the longer-term (> 5 year) impact of LDRD as a national asset. For example, a consistent process to track and understand the impact of projects so that it is clear which LDRD projects led to other activities.

4. There should be a similar degree of informal LDRD coordination between non-NNSA Labs as presently exists between the NNSA labs, as this may help spread and increase the impact of LDRD across the Lab system and beyond.

5. Some LDRD best practices at the Labs might be used more broadly. These could include designating a “lead reviewer” for all proposals, with duties beyond simply reviewing the proposal; the designation of “LDRD Points of Contact” within the major Lab directorates to play a critical role in ensuring program integration in all areas of the LDRD program; the requirement that every proposal develop an exit strategy to help maximize impact; and a requirement for a clear statement of how every proposal benefits DOE in the annual reports.

Summary

- The overall view of the Subcommittee is that the LDRD Program provides a unique combination of high-level Lab-driven strategic research and “blue sky” investigator driven fundamental research based upon individual innovation in a framework that has constructive federal, Lab and external oversight at multiple levels.
- Overall, the LDRD program appears to be very well run and monitored, in accordance with the intent of the DOE program, and with processes that couple innovation at the Lab and individual scientist level with the nation’s anticipated future security, energy, science, and engineering needs.
- Both the level of funding and the LDRD funding mechanisms are appropriate and necessary for the Labs to continue to perform at their present high quality level in R&D for the DOE Office of Science and NNSA.
- A more systematic approach to monitoring the long-term impact of the LDRD program at the Labs, tailored to the characteristics of each individual Lab, would make it easier for the great successes of the program to be more widely understood and appreciated.

Appendix A - Charge Letter

Department of Energy
Office of Science
Washington, DC 20585

Office of the Director

May 19, 2016

Professor Daniel A. Reed, ASCAC Chair
Office of the Vice President for Research and Economic Development
University of Iowa
2660 UCC
Iowa City, IA 52242

Dear Professor Reed:

Thank you for your continued service to the Office of Science (SC) and the scientific communities that it serves as the Chair of the Advanced Scientific Computing Advisory Committee (ASCAC). Thank you for the committee's latest report assessing the quality and effectiveness of the Office of Science and Technical Information's (OSTI) recent and current products and services. This report will help both SC and OSTI transition its products and services to methods appropriate to the new era of information gathering and sharing.

I am writing to ask that ASCAC address a particularly important cross-cutting issue in the Department of Energy (DOE), namely an independent review of Laboratory Directed Research and Development (LDRD) work of the DOE Laboratories (Labs).

The objectives of the LDRD program are to: (1) maintain the scientific and technical vitality of the Labs; (2) enhance the Labs' ability to address current and future DOE and National Nuclear Security Administration (NNSA) missions; (3) foster creativity and stimulate exploration of forefront science and technology; (4) serve as a proving ground for new concepts in R&D; and (5) support high-risk, potentially high-value R&D. DOE policy allows the Secretary of Energy to authorize up to 6% of a DOE Lab's total operating and capital equipment budget, including non-DOE funded work, for LDRD work.

The June 17, 2015, the interim report of the Secretary of Energy Advisory Board (SEAB) Task Force on DOE National Laboratories recommended an independent peer review of the LDRD program impacts and process of four laboratories, evaluating up to ten years of funded projects. I am asking ASCAC to review the LDRD program processes and the impact of LDRD at four of the DOE Labs, to include at least one SC Lab, one NNSA Lab, and one of the applied energy Labs. Please choose Labs that have had LDRD programs for at least ten years.

In your review, please consider each Lab's processes to:

- determine the funding levels for the LDRD programs;
- determine Lab-specific goals and allocate resources among the goals;
- select specific projects; and
- evaluate the success and impact of the LDRD program against Lab-specific goals and the overall objectives of the LDRD program over a ten-year period.

Printed with soy ink on recycled paper

In assembling a subcommittee, please consider members of or recommendations from the other Office of Science Federal advisory committees, the Defense Programs Advisory Committee, the Environmental Management Advisory Board, and the Nuclear Energy Advisory Committee.

The output of this review should be a brief report with an Executive Summary suitable for a general audience. The report should be available in the spring of 2017. We look forward to the results of your review and any recommendations that result from this study.

Sincerely,

C. A. Murray
Director, Office of Science

Appendix B - Subcommittee Members

The ASCAC LDRD Panel is composed of the following members drawn from various DOE Advisory Committees. The panel members are:

Professor Martin Berzins (Chair)
SCI Institute and School of Computing
University of Utah
72 S. Central Campus Dr., Rm 3750
SCI INSTITUTE
Salt Lake City, UT 84112

Dr Dawn A. Bonnell
The University of Pennsylvania
College Hall, Suite 118
Philadelphia, PA 19104

Dr Jolie Cizewski
Department of Physics and Astronomy
Rutgers, The State University of New Jersey
136 Frelinghuysen Road
Piscataway, NJ 08854-8019 USA

Dr Karsten M. Heeger
Professor of Physics
Department of Physics
Wright Laboratory
Yale University
PO Box 208120
266 Whitney Avenue
New Haven, CT 06520-8120, USA

Professor Tony Hey
Chief Data Scientist
Science and Technology Facilities Council, UK
Rutherford Appleton Laboratory
Harwell Campus
Didcot OX11 0QX

Christopher J. Keane
Vice President for Research
Professor of Physics
Washington State University

Lighty Student Services Building Room 286
PO Box 641060
Pullman, WA 99164-1060

Dr. Beverly A. Ramsey
Executive Director of DEES
Division of Earth and Ecosystem Sciences
Desert Research Institute,
Nevada

Dr. Karin A. Remington
President, Chief Science Officer
Computationality, LLC
13118 Deer Path Lane
Germantown, MD 20874

Dr Joy Rempe. Principal
Rempe and Associates, LLC
360 Stillwater
Idaho Falls, ID 83404

Appendix C - Charge to the Labs in Preparation for Site Visits

We include here the communication sent by the reviewing Subcommittee to the Labs selected for site visits. This communication helped to express what our Subcommittee would be looking for, and was geared to ensure that the Labs get a uniform message about how to prepare for our visits.

Date: November 12th, 2016
To: Rokaya Al-Ayat (LLNL), Barbara Goodman (NREL), Darren Ho (LBL) and John Neal (ORNL)
From: Dr. Martin Berzins, Chair
Subcommittee for the LDRD Program Review, of the
Advanced Scientific Computing Advisory Committee (ASCAC)
Re: Guidance for preparing for the LDRD review visit

The purpose of this correspondence is to provide background information and preparation guidance for the forthcoming Laboratory (Lab) visit in early 2017 by the ASCAC Subcommittee reviewing the LDRD program. We hope that you find this information helpful in structuring our visit to your particular Lab. Thank you in advance for your assistance as we respond to our charge from the Director of the Department of Energy's Office of Science, Dr. C.A. Murray (attached). It is worth noting here that the focus of the charge is strongly **process** oriented. Clearly, though, illustration of how well these processes work will require actual project examples, particularly to illustrate the impact of the high quality science and engineering that has emerged from the LDRD program. As you review the charge, please keep that process-oriented viewpoint in mind. For our review to be as consistent as possible, we want to ensure that each Lab has the same guidance. To that end, if anything is unclear after reviewing these guidelines, please contact us as soon as possible, and before December 16th, to ask for clarifications, so that we can make sure each Lab will get any needed additional guidance from us.

Dr. Murray's charge letter reads: "I am writing to ask that ASCAC address a particularly important cross-cutting issue in the Department of Energy (DOE), namely an independent review of Laboratory Directed Research and Development (LDRD) work of the DOE Laboratories (Labs)." We urge you to read through the details in that charge, if you have not already done so, so that you have an understanding of our goals as you are making preparations for the review. This charge led to the formation of an ASCAC Subcommittee to organize and conduct the review and report back through ASCAC to Dr. Murray. The panel members are listed at the end of this document for your reference.

Also, for your reference, the ASCAC designated Federal Official is:
Christine Chalk Christine.Chalk@science.doe.gov.
The Chair of ASCAC is:
Dr Dan Reed, University of Iowa, dan-reed@uiowa.edu.
The Chair of the assembled review Subcommittee panel is:

Dr. Martin Berzins, University of Utah, ASCAC, mb@sci.utah.edu.

1. Visit Format

In the visit the Committee would like you to explicitly address the main aspects of the charge through presentations and written material that describe your Lab's processes to:

- determine the funding levels for the LDRD programs;
- determine Lab-specific goals and allocate resources among the goals;
- select specific projects; and
- evaluate the success and impact of the LDRD program against Lab-specific goals and the overall objectives of the LDRD Program over a ten-year period.

In doing so the committee would like to spend time in sessions, if possible, with:

(i) Lab management;

(ii) The Lab LDRD Program Director;

(iii) Directors of different Programs/Directorates hosting LDRD to understand the different approaches required for theoretical, computational and experimental LDRD projects;

(iv) Technical community leaders involved with LDRD proposal mentoring, review, selection, and progress review, including senior-level technical leaders, such as Laboratory Fellows, who are involved with the technical peer review of the LDRD proposals.

(v) LDRD Principal Investigators (PIs). We would like meet with about 20 Lab PIs in a poster session. The PIs selected should include early- (including postdocs), mid-, and senior-career staff and represent a variety of projects including experimental ones. We would like to give these PIs a chance to showcase their work, and share their individual experiences with the LDRD program.

(vi) Three or four of the LDRD PIs, to dive deeper into the following areas:
   a. The goals of their research projects;
   b. How this research meets the overall goals of their Lab's LDRD program;
   c. The metrics by which they and their management evaluate their progress during periodic reviews;
   d. How they define 'success' for their project.

(vii) Where appropriate, a briefing identifying key examples where LDRD advances in your classified portfolio have supported laboratory program goals. We have committee members with clearance, so this briefing can be just to that smaller subgroup if it is not possible to formulate an unclassified briefing for the entire visiting group.

2. Scheduling and agenda for the visits

The panel will visit the four DOE Labs selected for this review on the following dates in 2017:
[Note: this table is behaving poorly… Karin will re-enter it soe that it comes out smoothly]

LBNL:	Wednesday, January 4th
LLNL:	Thursday, January 5th
ORNL:	Thursday, January 26th
NREL:	Thursday, February 2nd

The visits are expected to take one full day, with the exception of LLNL, for which, due to the volume of projects and the classified nature of some projects, we are allowing for additional time on a second half-day.

We ask each Laboratory to propose a full-day (or, for LLNL, one and a half day) agenda that will be suitable for the environment and logistics at your site. The agenda should include sessions for meeting with the groups referenced above, along with three executive sessions (at the beginning, roughly midway, and at the closing). We are happy to have a working lunch to fit in an executive session or one of the other sessions. As the visit proceeds, we may request some spontaneous executive discussion, and trust that the agenda can be accommodating should we need to make minor adjustments. Please send your proposed agenda to the Committee Chair for review and approval at your earliest convenience, and at least two weeks prior to your scheduled visit.

3. Preliminary Written Material Request

We ask each Laboratory to provide preliminary information to the Committee including an overview of your LDRD Program goals, funding profile over the last 10 years (by directorate or other organizational breakdown), and current areas of research.

Additionally, we would like to ask you to be responsive to the detailed points listed in the next section, and send us your responses in advance to allow for more in-depth conversation during our time with you in person. We very much look forward to hearing from you and will be happy to address any questions that you might have while preparing for the review visit. As mentioned above, please send us any questions for clarification no later than December 16th, so that all Labs will get the same guidance prior to their review visit.

4. Addressing the Charge in Detail

4.1. Funding Levels and LDRD Program Organization:

- Please explain the **process** by which the LDRD funding level is determined and how this has served Laboratory needs, both short term and long term (over the last decade).
- What fraction of the laboratory R&D budget is allocated to LDRD projects each year, and how are LDRD **costs** allocated (e.g., all programs are ‘taxed’ equally)?

- Please explain the management structure for the LDRD program, including the role of the Director's Office, the LDRD Program Office, and the individual Directorate Offices.

4.2. **Laboratory Specific Goal Setting:**

- Please describe the current set of LDRD goals within your Laboratory and explain the **process** by which Lab-specific LDRD goals are set. The goal set should distinguish between categories such as 'blue sky' fundamental research, major focused initiatives, fundamental research supporting the scientific base of major programs, or analogous categories you may use.
- Please provide examples of these goals over the last decade and how they were aided/realized by this process.
- Please explain the **process** by which resources are allocated between different goals and how the obtained results justify the use of this process.
- Describe what, if any, oversight **process** there is with respect to selecting laboratory goals?
- Are the Lab-specific goals for the LDRD program published? If so, are they consistent with the goals listed in our charge letter?
- Is there any effort to coordinate with other DOE and NNSA laboratories to coordinate and/or minimize duplication of capabilities within DOE/NNSA laboratories?

4.3. **Selection Process**:

Please describe the **process** by which specific projects were selected and explain the changes in the selection procedure over the last decade, if any. Of interest are:

- What mentoring is provided to prospective LDRD PIs, including early career and postdoc staff?
- Is there an open call published Laboratory-wide, or is the call to a smaller group?
- Does such a call specify topic areas of interest? If so, how are these topic areas selected and who proposes them?
- What must be submitted by Principal Investigators (PIs) responding to the call?
- Are the metrics for evaluating proposals published in the call?
- Describe the **process** of project selection from the suite of proposals, for example:
  - Identify the composition of the selection committee and any policies regarding its composition. Has that been consistent, or evolving over time?

    - Is the selection done solely based on technical peer review results, or is there a management 'strategic' evaluation that is also considered?
    - How much interaction is there by DOE/NNSA oversight organizations in developing the call and selecting projects?
- What are the success rates for LDRD proposals?

4.4. **Success determination**:

- Please describe the **process** used to evaluate the success or failure of LDRD projects, including the frequency of evaluations and the composition of any panel(s) (e.g., management, technical staff, etc.) conducting these evaluations.
- What factors influence the 'success' of LDRD projects? Explain which metrics have been used in this **process** and how those metrics correspond to traditional research metrics (papers, future funding), lab strategic goals (new programs, capabilities, initiatives, areas). Are these published in advance? Have they evolved over time? Please provide examples to illustrate if this would be helpful.
- Explain the termination criteria for LDRD projects.
- What have been the success rates for funded LDRD projects throughout the past decade? That is, how often have LDRD projects been terminated?
- Please explain the **process** by which the success of LDRD relates to the ability of the Laboratory to undertake its core DOE mission and other agency work through workforce development.
- Portfolio Detail: A report listing your LDRD projects in whatever format you use for internally. We expect to see PI and affiliation, project title, funding level, start date, end-date, success metrics, etc., and are also interested in how you use reporting in your process.

Appendix D - Detailed Site Visit Reports

Lawrence Berkeley National Laboratory – Berkeley, California

Summary

- The purpose of Berkeley Lab's LDRD program is to be a tool for maintaining the Lab's position at the forefront of science.
- It enables high risk R&D by experts assembled from different fields into teams whose collaboration uncovers synergies and multidisciplinary solutions not otherwise evident.
- It serves as a proving ground for advanced concepts that are often subsequently pursued by DOE programs and help identify more creative approaches to fulfilling future mission needs.
- The LDRD program is instrumental in the Lab's ability to attract promising young scientists and engineers.
- A small fraction of the budget, the LDRD has a disproportionate impact on Lab's success.

Overview of LBNL and the LDRD program

Background

LBNL in Berkeley is a member of the National Lab system supported by the U.S. Department of Energy through its Office of Science. It is managed by the University of California (UC) and is charged with conducting unclassified research across a wide range of scientific disciplines.

The LBNL vision is to foster groundbreaking fundamental science that enables transformational solutions for energy and environment challenges, using interdisciplinary teams and by creating advanced new tools for scientific discovery.

The Lab supports a very diverse R&D portfolio covering the areas of energy sciences, energy technologies, computing sciences, physical sciences and the bio and environmental sciences. This wide range of research provides great opportunities both for developing new technologies that have significant societal impact, and for doing great science. Research at the Lab is carried out using three approaches:

- Investigator research programs
- Team science, usually with other labs and partners
- User facilities and other advanced tools

Berkeley Lab's User Facilities provide state-of-the-art resources for scientists across the nation and around the world. About 10,000 researchers a year use these facilities, representing nearly one third of the total for all Department of Energy Office of Science User Facilities.

The five Berkeley User Facilities are:

Advanced Light Source

Berkeley Lab's Advanced Light Source (ALS) is an electron accelerator/storage ring that serves as one of the world's premier sources of X-ray and ultraviolet light for scientific research ranging from advanced materials to protein crystallography and 3D biological imaging. As a DOE national user facility, the resources of the ALS are available to qualified users around the world, attracting more than 2000 researchers and students annually.

Molecular Foundry

The Molecular Foundry is a DOE-funded program providing support to researchers from around the world whose work can benefit from or contribute to nanoscience. Through unparalleled access to state-of-the-art instruments, materials, technical expertise and training, the Foundry provides researchers with the tools to enhance the development and understanding of the synthesis, characterization and theory of nanoscale materials.

Joint Genome Institute

The mission of the U.S. Department of Energy's Joint Genome Institute (JGI) is to advance genomics in support of the missions related to clean energy generation and environmental characterization and cleanup. JGI provides integrated high throughput sequencing and computational analysis that enable systems-based scientific approaches to these challenges.

Energy Sciences Network

The Energy Sciences Network (ESnet) provides the high-bandwidth, reliable connections linking scientists at National Labs, universities and other research institutions, enabling them to collaborate on some of the world's most important scientific challenges including energy, climate science, and the origins of the universe. Funded by the DOE Office of Science, and managed and operated by Berkeley Lab, ESnet provides scientists with access to unique DOE research facilities and computing resources.

National Energy Research Scientific Computing Center

The National Energy Research Scientific Computing Center (NERSC) is the primary scientific computing facility for DOE's Office of Science and a world leader in accelerating scientific discovery through computation and data analysis. More than 5,000 scientists use NERSC to perform basic research across a wide range of disciplines, including climate modeling, high energy physics, new materials, simulations of the early universe and a host of other scientific endeavors.

Berkeley Lab employs approximately 3,232 scientists, engineers and support staff. The Lab's total costs for FY 2014 were $785 million. A recent study estimated that the Laboratory's overall economic impact through direct, indirect and induced spending on the nine counties that make up the San Francisco Bay Area to be nearly $700 million annually. The Lab was also responsible for creating 5,600 jobs locally and 12,000 nationally. The overall economic impact on the national economy is estimated at $1.6 billion a year. Technologies developed at Berkeley Lab have generated billions of dollars in revenues, and thousands of jobs. Savings as a result of Berkeley Lab developments in lighting and windows, and other energy-efficient technologies, have been in the billions of dollars.

Purpose of LDRD at LBNL

The LDRD program at DOE serves several purposes:

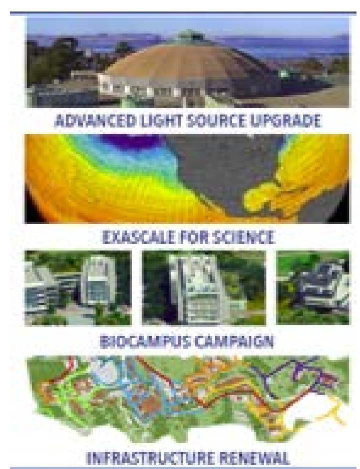
1. Maintain the scientific and technical vitality of the Labs
2. Enhance the Labs' ability to address current and future DOE and NNSA missions
3. Foster creativity and stimulate exploration of forefront science and technology
4. Serve as a proving ground for new concepts in R&D
5. Support high-risk potentially high-value R&D

At LBNL, the stated purpose of the LDRD funding is two-fold and is well-aligned with the overall DOE objectives:

- Seed funding for advanced scientific ideas in established DOE fields and establish expertise in areas that DOE may move to in the future
- Strengthens S&T workforce through recruitments, retentions, and cascading new hires of early career staff (scientists, post-docs, and students)

Each year, the Lab Management sets Lab-wide Strategic Priorities and Initiatives with a structured planning process that engages staff and leadership over 24 months. For 2017, the four top Lab strategic priorities are:

- Advanced Light Source upgrade
- Exascale for Science
- Biocampus
- Infrastructure renewal



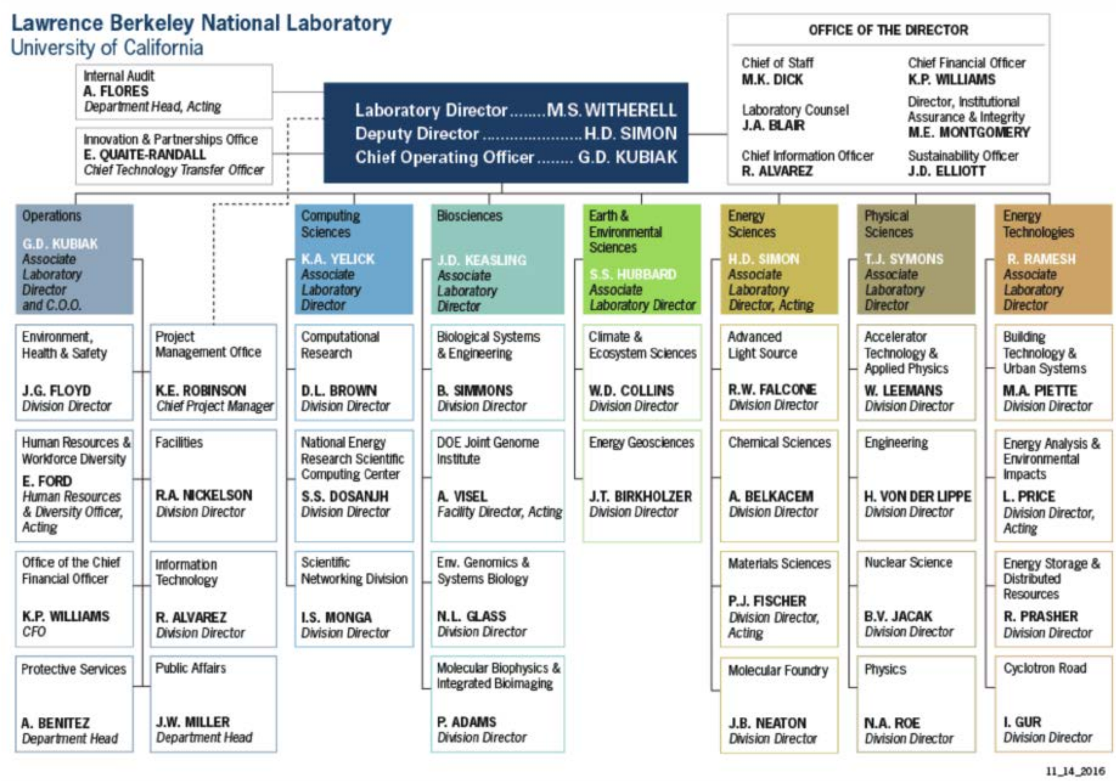
The six strategic initiatives for the 2017 LDRD program are:

- Next Generation of Scientists
- Microbes to Biomes
- Electron Microscopy
- Water-Energy Nexus
- Beyond Moore's Law
- Data Analytics for Science

LDRD projects for each of these initiatives typically span two or more science areas. Approved projects generally run for two years with a maximum of three.

LBNL Organization

The six science areas report into the Lab Director's Office and the ALDs of these areas play a key role in selecting the LDRD projects. The Deputy Lab Director has specific oversight responsibility as the LDRD Program Manager.



Agenda for the ASCAC LDRD Review

The on-sight review was structured to provide the Subcommittee with information regarding the organizational structure, processes for strategic planning and examples of the processes and outcomes around the LDRD program. These materials/discussions supplemented the reports available to the Subcommittee throughout the process, which included 10 yr plans and the last 5 annual reports.

- Overview and Strategic Directions from Lab Director (Witherell)
- LDRD projects and highlights from Deputy Lab Director (Simon)
- LDRD Selection Processes and Management (Ho)
- ALD Roundtable “LDRD as a Critical Investment for New Laboratory Directions” (Yelick/Keasling/Collins for Hubbard)
- PI Roundtable “LDRD as a Critical Investment for Major Scientific Breakthroughs” (Brodie/Persson/Saxena/Sethian/Ushizima)
- LDRD Project Poster session
- Meeting with Site Field Office
- Private Subcommittee discussion

- Feedback to LBNL Management

Following the Subcommittee visit, LBNL provided additional information in response to the following three specific questions.

- A few examples of how LDRD projects led onto other projects. How did LDRD projects (or a group of projects) lead to new areas of R&D?
- How does your laboratory use LDRD to respond quickly to new initiatives and times of crisis? This includes the foundational work of LDRD to build capabilities needed for future missions as well as the people who were funded through LDRD.
- Can you provide the breakdown of costs (% is fine) of the LDRD areas of interest? Can you provide a trend of how this has been broken down over the past ten years?

Overview of LDRD organization at the Lab

The LBNL Lab Director and Deputy Director are responsible for the overall execution and management performance of the LDRD program. The Deputy Director has been designated as the LDRD Program Manager and has overall oversight responsibility.

The Associate Lab Directors (ALDs) and Division Directors are responsible for providing scientific and strategic insight to the Lab Director and Deputy Director in selecting the research topics in the LDRD Call for Proposals. They must also monitor fiscal and scientific oversight and provide management of the principal investigators and projects in their divisions.

The Lab LDRD Office is responsible for the LDRD program administration, reporting, and compliance. The LDRD Administrator in coordination with the Lab Budget Office monitors the approved project budgets and expenditures by controlling account openings and closings, reviewing and authorizing project funding and scope change requests, and ensuring the program expenditures conform with required accounting procedures.

Processes for determining funding levels at lab level (interactions with HQ, etc.)

In April/May of each year, Divisional Spend Plans are used to derive the out-year LDRD distribution base. In July/August, as part of Indirect Budget Formulation, the Lab Senior Management develops the preferred level of LDRD funding. In September, just prior to the new fiscal year, both estimates are finalized. The LDRD rate is the result. LBNL historically uses ~3.5% of total Lab funding for the LDRD program (compared to the maximum possible of 6%). This amounts to about $25M each year for the Berkeley LDRD program.

The LDRD program plan is submitted to the Lab's site office to request permission for the program funding rate for the following year. The site office coordinates with DOE HQ and funding authorization is then granted.

At the end of the year, the Lab must submit an Annual Report and provide project and program financial data to the DOE CFO's office.

Development of the LDRD call (how it relates to lab-specific goals and resource allocation between these various goals and strategies)

The LDRD process to develop the Call for Proposals, to review the submitted proposals, and to make funding decisions takes place over a two-year cycle:

Year 1

- January to April, the Lab Director develops the annual lab plan (ALP) with ALD input.
- May/June, the Lab's ALP is presented to DOE.
- September/October, the ALDs develop input for the LDRD call with ALP information.
- December, the LDRD Call for Proposals is issued.

Year 2

- January/February, Lab-wide discussions of strategy, proposal idea development.
- March, LDRD proposals submitted.
- April/May, Proposals reviewed.
- June/July, Funding decisions and DOE approvals.
- October, LDRD projects start.

The ALDs work with the LDRD Lab Management to define the Lab-wide 'Strategic Initiatives': with their Division Directors, the ALDs also decide on their scientific 'Area Priorities'. This is an interactive process during which much communication across divisions informs the outcomes.

Detailed selection processes for projects in different goals/areas (review process)

In the selection process the following key questions or criteria are considered:

- Quality of science
- Consistency with Berkeley Lab's core capabilities
- Extent to which a DOE need is addressed
- Realistic potential for becoming a large programmatic direction for DOE

Funding is only guaranteed for one fiscal year and continuations must provide progress reports, current FY plans, and a comment on prospects for follow-on funding.

The Call for Proposals (CFP) requirement – via an online submission system – is for a short summary of the proposed LDRD project comprising:

- Cover sheet
- Three-page technical proposal with an additional page for facts and figures
- Budget request form
- Safety/IP forms

Both the Area Priorities and Lab Initiative LDRD proposals are ranked by the ALDs and their Division Directors (DDs) into 'Forced Ranked Lists. The process is as follows:

For Area Priorities proposals

- Area proposals are continuously reviewed by DDs and ALDs and feedback to the proposers is provided during the process if requested. A similar process is conducted by most of the Areas. Proposals PIs are given an opportunity to write a short pre-proposal that is reviewed by the ALD, DDs, and other senior research staff. During the writing process, the PI is encouraged to get feedback by other subject matter experts which may include other staff scientists or Area/Division office staff. Following this initial feedback, the PIs typically write and submit a full technical proposal with detailed budget information provided. In preparation for review at the Directorate level, the PIs are then invited to give short presentations, which are critiqued and analyzed by the Area teams. Reviewers may suggest tweaks, edits, or additions to the proposal at this point, which the PI may or may not incorporate before final review at the Directorate level.
- The DDs are allowed autonomy to use whatever review format works best for their Divisions. The 'standard model' consists of a review by senior managers or a review committee that assesses each proposal according to the following criteria:
    - Quality of science
    - Program relevance
    - Scientific risk and novelty
    - Uniqueness of organization structure
- The Division Director then passes along a ranked list of projects to the area ALD for their review. After this review, the ALD consults with DDs and re-ranks all proposals into the Area Priority list.

For Lab Initiative proposals

For Lab-wide proposals, a similar process is followed, led and ranked by the designated Lab Initiative lead. Lab Initiative proposals usually involve more than one science area.

Lab initiative Proposal Presentations and Review

- From the ranked list of Lab Initiative proposals about 20 to 25 proposals are selected to present to Directorate staff – the LD, Deputy LD, ALDs and DDS.
- Berkeley Site Office staff are also invited as observers for these presentations.
- Each PI is given 15 minutes to make a presentation and 5 additional minutes for Q/A.
- The Directorate staff deliberate and rank the proposals
- Finally, after the presentations, Berkeley Lab's Directorate staff goes through a funding simulation exercise. The exercise totals up the full funding amount requested by the Lab Initiative proposals and multiplies it by 60%. The ALDs, DDs, and other Directorate staff are then asked to fund projects with this reduced amount as if they were the final decision maker. They have found that this effort produces better results in determining funding priorities for proposals versus independent 1-5 ratings for each proposal. In effect, it pits Lab Initiative proposals against each one, which is especially important when funding dollars are also limited.)

Area Initiative Proposal Presentations and Review

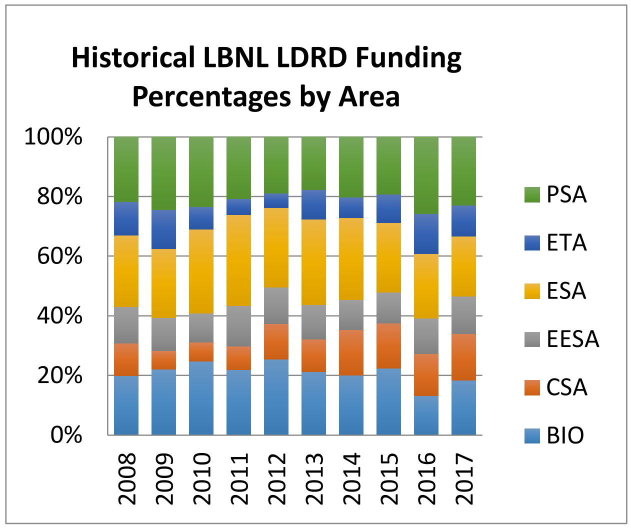
- Fifteen to twenty proposals are chosen to be presented in bulk by the respective ALD to the same Directorate staff.

- Three to five minutes are devoted to each proposal.

The Lab does not set predetermined quantitative targets or metrics prior to the selection of the projects. Each proposal is judged on an individual, independent basis and in response to current and future needs. Each proposal's specific case is then weighed on its own merit in combination to its applicability to a specific scientific area and overall Lab portfolio.

The 2017 LDRD project portfolio

The total number of LDRD projects funded in the years from 2013 to 2017 varies from 94 out of 231 proposals submitted in 2013 to 88 out of 166 in 2017. In 2017, 26 projects of the 88 LDRD projects were Lab Initiative projects and 62 were Area Priority projects. From these selected projects, 27 of the 88 were 'People' related, and directly assisted with Lab recruitment and retention. The distribution of the LDRD funding amongst the science areas varies from year to year as a natural outcome of the review process.



PSA – Physical Sciences Area
ETA – Energy Technologies Area
ESA – Energy Sciences Area
EESA – Earth and Environmental Sciences Area
CSA – Computing Sciences Area
BIO – Biosciences Area

Another approach to analyzing the Lab's LDRD project portfolio is in terms of those that are driven by Lab Strategy, those that are from individual PIs and those that are opportunistic:

Driven by Lab Strategy (top down): ~35%

- LDRD CFP sets targeted priorities that are aligned with Lab/Area strategy
- ALDs develop additional concepts through town hall meetings and workshops
- ALDs set LDRD priority themes for their areas
- Proposals for Lab Initiative and Area programs are reviewed

Individual PIs (bottom up): ~40%

- LDRD funding opportunities are open to individual ideas germinating at the researcher level
- Emerging leaders develop projects as part of their training, independent of any current research initiatives

- Early career development track

Opportunistic: ~25%
- Support for anticipated DOE calls for proposals
- Recruiting opportunities
- Retention
- Other

Processes for evaluating impact of LDRD against goals and laboratory objectives
As with research in division programs, all LDRD projects have extensive review and reporting arrangements.

For regular status updates:
- Division Directors send reports to senior management
- Continuation project updates are provided at periodic project reviews
- Change requests recording and spend rates are monitored

For research reporting as per Public Law 95-39, Section 303 and DOE Order 413.2C the following are submitted:
- Final report
- Funding trends (five-year table)
- DOE Office of Science LDRD program reviews
- Office of Scientific and Technical Information (OSTI)

The Lab also reviews outcomes of the LDRD program in terms of productivity as indicated by the numbers of new young scientists, staff retention, inventions and patents, publications, and peer recognition.

High-level overall impact of LDRD at the laboratory (including self-studies):

There is no doubt that the LDRD has both strategic and scientific impact on the LBNL program. This impact is partially quantified by the metrics regularly reported and listed above. In addition, LBNL provided many compelling success stories demonstrating the long-term impact of the Lab's LDRD projects. These examples are powerful tools for communicating the program's value to internal and external stakeholders. The following example illustrates how LDRD leads to transformative advances in basic science.

Computational Innovations to Measure the Parameters of the Universe (Saul Perlmutter) – The funding for Saul Perlmutter's LDRD project represented strategic support for a shift in his research that eventually led to the research for which he received his Nobel Prize. The work proposed was not funded by DOE or any other funding source as it was viewed as a dramatic shift in approach that was not yet fully tested. His LDRD project allowed Perlmutter to perform the proof of concept and initial stages of the research that was subsequently funded by DOE.

Detailed examples of processes through posters and deep dive into selected projects

The Roundtable "LDRD as a Critical Investment for Major Scientific Breakthroughs" with researchers Eoin Brodie, Kristin Persson, Samveg Saxena, Jamie Sethian, and Dani Ushizima provided the Subcommittee with a demonstration of how five exciting DOE programs originated from original Berkeley LDRD projects: the Microbe to Biome program, the Materials Genome initiative, a hybrid vehicle analytics smartphone app, the CAMERA cross-Lab project, and quantitative image analysis for computer modeling. This was followed by a detailed briefing on a selection of LDRD projects which elucidated the process by which each project was established and the potential for future impact. The Microbe to Biome example illustrates the power of the LDRD program to impact lab and national research directions.

Microbes to Biomes – As part of a leadership development program, three early career researchers came together to propose a new cross-cutting approach to examining the way in which microbes create and impact larger biomes. The nascent idea was then funded as an individual LDRD project. The following year, the idea grew into an Area Initiative project that was funded for several more years, bringing many other research community around the Lab together to push this concept further. Some participants involved also became instrumental in the national discussion of the Biome that has led to several of the current efforts being undertaken at the Federal level. This is a good example of how an LDRD funded project can help lead to drive future research directions.

Key observations from the visit

- The LDRD program at LBNL has been critical in enabling the Lab to make significant long-term investments ahead of any new DOE program.
- The LDRD program has also been critical in enabling the Berkeley Lab to strengthen in S&T workforce through recruitments, retentions and new hires of early career staff.
- The size of the LDRD program (3.6% for FY17) and its programmatic balance are appropriate to the goals of the lab, demonstrating that the processes for setting funding levels are effective.

- The quality of the science in Berkeley Lab's LDRD program is exceptional as exemplified by the Nobel Prize winning work by Perlmutter and the new DOE programs stimulated.
- The processes for mapping the LDRD program onto the goals of LBNL and DOE are an inherent part of the strategic planning of the lab. This very structured process ensures that all division activities are aligned, including and especially the LDRD program.
- LBNL's processes for selection and management of the LDRD projects provide the Lab with a good balance between top-down Lab-wide strategic projects and bottom-up individual PI projects.
- It is not clear how systematically the Lab collects long term longitudinal statistics of its LDRD projects that can ultimately result in very large impacts.

Lawrence Livermore National Laboratory – Livermore, California

Agenda and summary of information provided in advance

LLNL is a multi-mission, multi-program Lab and one of three DOE National Labs overseen by the National Nuclear Security Administration (NNSA). The LLNL mission is to strengthen U.S. security through the development and application of world-class science, technology, and engineering to:

- Enhance the nation's defense;
- Reduce the global threat from terrorism and weapons of mass destruction; and
- Respond with vision, quality, integrity, and technical excellence to scientific issues of national importance.

The LLNL vision is to:

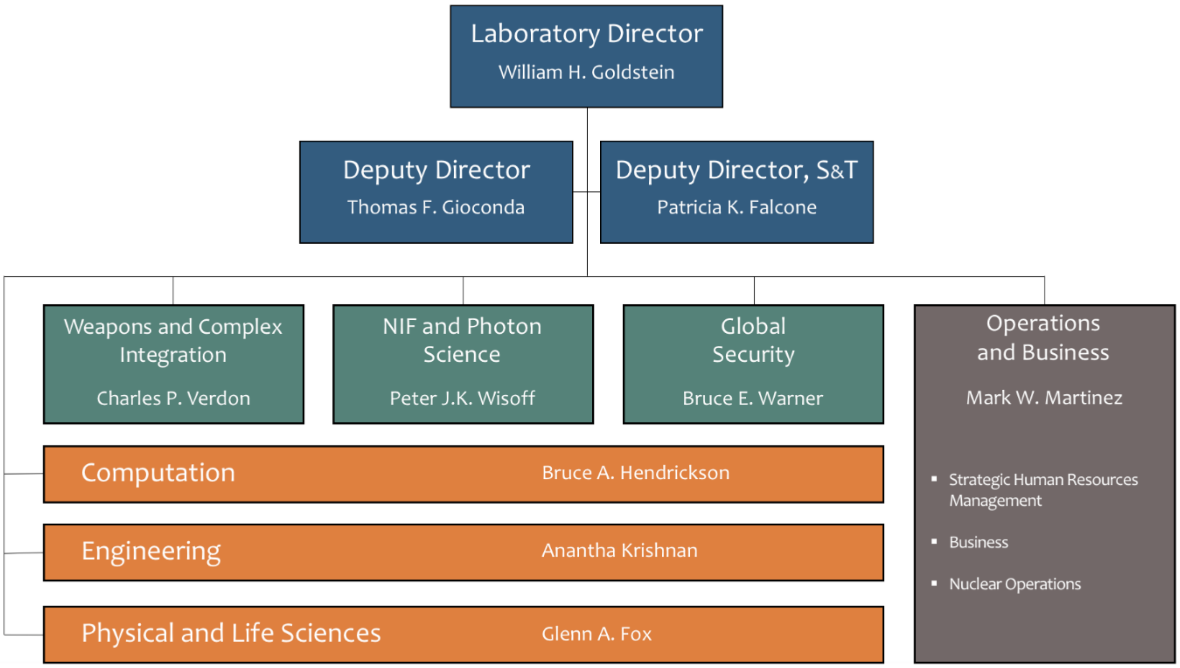
- Lead the nation in stockpile science, innovation and sustainment.
- Be the foremost National Security Lab, anticipating, innovating and delivering solutions for the nation's most challenging security problems.
- Be the premier destination for our nation's very best scientists and engineers.

The goals of the LLNL LDRD program, stated below, support this mission and vision.

The Lab has approximately 6500 employees and a total annual budget of $1.7B. The table below indicates how the FY2016 budget was distributed between the various sponsoring programs:

Organization/Mission	**FY2016 funding ($M)**	**FY2016 funding (%)**
NNSA Stockpile Stewardship	1088	64.6
NNSA- Nonproliferation	106	6.3
NNSA- Safeguards and Security	82	4.9
DOE Science and Energy	130	7.7
Dept. of Homeland Security	29	1.7
Department of Defense	191	11.3
Non-federal	59	3.5
TOTAL	1685	100

The Lab is organized using a "matrix model" that can be explained by reference to the LLNL organization chart:



LLNL includes three "program" directorates (Weapons and Complex Integration, Global Security, and NIF & Photon Science) and three "discipline" directorates (Computation, Engineering, and Physical and Life Sciences). In the matrix model, the bulk of science, technology, and engineering (ST&E) staff supporting the three program directorates is "matrixed" from the discipline directorates. Thus, the discipline directorates are the administrative home for the clear majority of LLNL's ST&E workforce. LLNL states this structure is very flexible and has been critical to the Lab's success. LLNL states it enables the required expertise to be quickly applied to a given problem, and ensures technical excellence in both the discipline and program directorates. The "matrix" also encourages discipline experts to move between program directorates, providing a continuous source of new ideas and techniques to the programs and a multidisciplinary career opportunity for ST&E staff.

LLNL submitted a great deal of information in support of the review, including:

a) Detailed written answers to the Committee's questions sent in advance
b) LLNL FY2017 LDRD Program Plan
c) FY2017 calls for proposals, of which there are three: 1) Exploratory Research and Feasibility Studies, 2) Strategic Initiatives, and 3) Lab-wide competitions.
d) A report entitled "LLNL Investment Strategy for Science, Technology and Engineering (ST&E)"-referred to in this document as the "LLNL ST&E Investment Strategy report." This report describes the LLNL strategy for ST&E investment.
e) A detailed listing of all projects from FY2007-FY2016, and LDRD annual reports for FY2006-FY2015.
f) Copies of all talks and posters presented at the January 5-6, 2017 Subcommittee site visit.
g) GAO, SEAB, and other reports of interest.

Strategic overview of LDRD (including Laboratory LDRD Office, internal organization, plans and proposed improvements)

DOE and LLNL LDRD program objectives are well aligned. LDRD-supported projects are essential to supporting the ST&E base of the Lab and meeting institutional goals. They are also necessary to maintaining and enhancing the Lab's core competencies and defining the LLNL strategic initiatives. These dynamic components- the core competencies, the initiatives, and the LDRD portfolio- are regularly re-examined to ensure the Lab's ST&E base is supportive of LLNL's evolving missions. The goals for the LLNL LDRD program, as well as the current set of core competencies and strategic initiatives, are listed below.

LLNL goals for LDRD support the Lab's mission and vision:
- Support the DOE/NNSA and LLNL missions and strategic vision;
- Ensure the technical vitality of the Laboratory;
- Attract and maintain the most qualified scientists and engineers, and allow scientific and technical staff to enhance their skills and expertise;
- Anticipate evolving DOE and national security needs of other federal agencies; and
- Enable scientific collaborations with academia, industry, and other government Labs.

The **LLNL core competencies** have been identified as targets for institutional investments:
- Advanced materials and manufacturing
- Bioscience and bioengineering
- Earth and atmospheric science
- High energy density science
- High performance computing, simulation and data science
- Lasers and optical science and technology
- Nuclear chemical and isotopic science and technology

The FY2017 **LLNL mission focus areas** are:
- Stockpile Stewardship Science
- Cyber Security, Space, and Intelligence
- Energy and Climate Security
- Chemical and Biological Security
- Inertial Fusion Science and Technology

LLNL has a ST&E strategic planning process to ensure that the Laboratory sustains its leadership in national security, as well as being responsive to a changing world. This effort engages working groups from across the Laboratory with key roles played by members of the senior management team. The outcome from this process, documented in "LLNL ST&E Investment Strategy report", discussed above, identifies the mission focus and core competency areas to be supported and the strategic importance of each. This report is updated annually. The LLNL strategy includes development of LDRD collaborations with other Labs when appropriate. The DOE HQ and Livermore Site Offices encourage joint LDRD efforts between the Labs where appropriate.

The LDRD program is well managed by a director who brings decades of experience and her deputy who is developing new tools to track the success of LDRD investments. The LDRD program reports to the Laboratory's Deputy Director for Science and Technology. Critical components of the LDRD infrastructure are the points of contact (POCs), one for each directorate, who mentor prospective PIs in developing a successful proposal and foster the inter-unit collaborations and success of the projects at all stages. They also coordinate the review of proposals before submission to the Laboratory's strategic initiative competition.

The LDRD deputy director serves an analogous role for the Lab-wide competition, where the early career staff and postdocs are mentored in developing successful proposals and ultimately successful projects. A critical component of all LDRD projects is the exit strategy – how this effort will have a longer-term impact – that is honed at all stages of the project, from proposal development and submission, to the mid-project review, to the project end and beyond.

The LDRD office has long tracked the contributions of LDRD project to measures of excellence in ST&E: publications, patents and copyrights, and internal and external awards that recognize excellence in fundamental and applied science, engineering and entrepreneurship. For each of these metrics, the LDRD office can reach back to trace the LDRD investment that realized these products. Throughout our visit and in annual reports, we heard stories of how LDRD-funded projects made seminal contributions to the full spectrum of national security programmatic activities of the Laboratory, from innovation in light-weight materials that enabled the development of light-weight structural mounts to address an important programmatic challenge, to paradigm changes in manufacturing that are saving tens of millions of dollars. (Specific examples of programmatic accomplishments enabled by LDRD are discussed in Section 8 below). The LDRD office is developing new protocols to capture all outputs of each project as a measure of the success of the entire LDRD effort at LLNL.

Processes for determining funding levels at lab level (interactions with HQ, etc.)

Because LDRD funding is so integral to the success of the ST&E efforts of the Laboratory, LLNL maximizes (to the level approved by Congress) the funds that are available for LDRD investments. Therefore, the funds available for LDRD projects are typically close to the maximum available based on the congressionally approved limit of the total Lab budget after subtracting the LDRD budget (or as close as possible, due to uncertainties associated with Lab funding). Typically, early in a given fiscal year, the LDRD office is given a projection for the funds available for the following fiscal year. Based on that projection, a plan for funding in the various LDRD categories is assembled and incorporated into the draft LDRD program plan which is submitted to the NNSA Livermore Site Office by August 15th. The Site Office approves the program plan, which is then executed starting October 1 and updated during the fiscal year as necessary.

As with the other Labs, the institutional LDRD funding level is discussed with, and ultimately approved by, the DOE/NNSA site office. The site office also reviews all proposed projects for alignment with mission areas and compliance with all DOE orders.

Development of the LDRD call (how it relates to lab-specific goals and resource allocation between these various goals and strategies)

Initially, LDRD resources are distributed as outlined in the LLNL ST&E Investment Strategy report. The 'science' and 'quality' of the proposed project will ultimately govern LDRD project selection. However, LLNL has found that their five LDRD program goals are best achieved if resources are divided into four categories (with the approximate allocations shown for FY2017):

- **Strategic Initiative (SI)** projects are intended to make major advances in strategic focus research or core competencies. Typically, these are large (ranging from $1.5 to $3.0M/year), three-year projects and involve a multidisciplinary team to attack a technically challenging issue and bring a new capability to LLNL. In FY2017, approximately 21% of LDRD resources were allocated for SI projects.
- **Exploratory Research (ER)** projects are designed to address LLNL directorate strategic research and development areas and workforce development needs. These three-year projects (typically less than $1.5/year) align with the core competencies and the mission focus areas outlined in the LLNL ST&E Investment Strategy report. In FY2017, approximately 70% of LDRD resources were allocated for ER projects.
- **Laboratory-Wide Competition (LW)** projects (maximum funding of $300 K/ year) are chosen to emphasize innovative research concepts and ideas, with very limited management filtering to encourage the creativity of individual researchers. The LDRD office has taken actions, such as proposal-writing and presentation review sessions and funding level limits (typically less than $300 K/year), that encourage early career scientists and engineers to seek LW funding for these typically two-year projects. In FY2017, approximately 6% of LDRD funds were allocated for LW projects.
- **Feasibility Study (FS)** projects provide researchers with the flexibility to propose small (less than $175 K) short-term studies efforts to determine the feasibility of a specific technical concept for addressing a mission-relevant challenge. Although FS projects are limited to 1 year, they may start anytime during a year and may span fiscal years. In FY2017, approximately 3% of LDRD resources were allocated for FS projects.

The breakdown of the funding into the four categories above has been relatively stable over the past 10 years.

Detailed selection processes for projects in different goals/areas (review process)

As discussed above, the four categories of LDRD proposals are SI, ER, LW, and FS. Proposal calls for the SI, ER, and LW categories are developed and issued separately. The FS call is described within the ER solicitation, though FS proposals may be submitted at any time.

Processes used to develop calls and proposals differ for various LDRD categories and within the Lab. Each program and discipline select processes that best enable them to meet their strategic goals. There is top down management input from across the Lab that influences development of SI proposals. In addition to seeking input from staff and management, some leads developing SI proposals seek input from external experts. Multiple organization proposals are encouraged. The matrix organization enables the collection of diverse perspectives; programmatic input to ensure that existing or future mission needs are met; and discipline input to ensure that improvements to core capabilities for a broad range of programs are considered.

All proposals are reviewed by at least one of the following review committees:

- Advanced Materials and Manufacturing
- Chem-Bio Security, Bioscience, and Bioengineering
- Cyber Security, Space, and Intelligence
- Energy, Earth, and Atmospheric S&T
- High Energy Density Science (also covers Stockpile Stewardship Science)
- High Performance Computing, Simulation, and Data Science
- Lasers and Optical Materials
- Nuclear, Chemical, and Isotropic S&T

The discipline orientation of the review committees supports the goal of in-depth technical review. More than one committee may be involved in reviewing multidisciplinary proposals.

A summary of the review process for each of these proposal types appears below:

Strategic Initiatives (SI): Larger, interdisciplinary SI proposals usually have a more "top down" flavor than the other proposal types. The SI process starts with the LLNL Director issued call, typically in the January-February timeframe. PIs then develop and submit whitepapers to the LDRD office for review by the Laboratory S&T Council. The S&T Council consists of the three program Principal Associate Directors, three discipline Associate Directors, Deputy Director for Science and Technology, LDRD Program Director, and the six POCs. The S&T Council reviews the whitepapers for mission relevance and quality, and typically reduces the set of SI whitepapers to approximately twice the available funding. PIs prepare full proposals, typically 25 pages long, for whitepapers endorsed by the S&T Council. The appropriate LDRD committee or committees then review the full proposals. Each PI appears before the committee for approximately 45-60 minutes to present the proposal. Each proposal is assigned a lead and secondary reviewer, drawn from the committee. It is the job of these reviewers to be familiar with the details of the proposal, meet with the PI and team ahead of the committee review, and lead discussion of the proposal during review committee deliberations. Each committee scores their proposals and ranks them using an electronic system. Individual committee results are forwarded to the LDRD office, where an integrated ranking of all SI proposals is prepared. The LDRD office reviews these rankings with the Laboratory S&T Council, and then makes a final recommendation to the Laboratory Deputy Director for Science and Technology and the Laboratory Director. The Director and Deputy Director, in consultation with the S&T Council, make the final decisions, with approximately one of out of every four full proposals funded. The LDRD POCs play a critical role throughout the process, ensuring appropriate technical coordination for the proposal itself as well as the review process.

Exploratory Research (ER) proposals: The process for selecting ER projects is similar to that used for Strategic Initiatives, with several important differences. Senior leaders from the program and discipline directorates, as well as the LDRD POCs and focus area leaders, perform the whitepaper screening process. Full ER proposals are typically six pages long, versus 25 for Strategic Initiatives. The Committee review and award process is similar to that used for Strategic Initiatives. LLNL funds approximately one out of every 10 ER proposals. Note that proposals that are not accepted as SI projects could be re-scoped for consideration as part of the ER review and selection process.

Lab-wide (LW) proposals: There is no whitepaper screening process for proposals submitted to the LW competition. The 18-member lab-wide review committee reviews the lab-wide proposals. The review committee selects a short list of proposals for 30-minute oral presentation. The lab-wide committee develops a final proposal ranking, with funding for each project based on available funds. The Director and Deputy Director for S&T make the final decisions. The success rate for LW proposals is about one in ten.

Feasibility Study (FS) proposals: PIs may submit FS proposals at any time. Feasibility Study proposals follow the same review and selection process as ER proposals.

The lead reviewer of each proposal that reaches the Lab-level competition plays a unique-to-LLNL role beyond just reviewing the proposal. The lead reviewer also serves as a steward of each project. The lead reviewer prepares the PI for the oral presentation, and in many cases, works with the PI to ensure success throughout the project, mentors the evolution of the exit strategy, and helps to connect the PI and project with collaborators and appropriate programmatic staff.

Processes for evaluating impact of LDRD against goals and Lab objectives

Each project is formally evaluated, at a minimum, on an annual basis. The LDRD POC within each organization monitors, tracks progress, and identifies any issues that may arise for each project. These issues are discussed and addressed with the LDRD Program director. Additional reviews are conducted for each project, but the frequency and type of review varies for each type of project (e.g., SI projects receive more frequent reviews than ER projects).

Review criteria are published and communicated to the principal investigators and the broader LLNL community. On an annual basis, investigators are required to submit the traditional metrics (e.g., publications, citations, CRADAs, patents, copyrights and awards, as well as new hires, employee retentions, new programs, etc.). These metrics are reported as part of the LLNL LDRD annual report. In addition, to gain funding approval from the DOE Field Office, the principal investigator submits a list of milestones accomplished and tasks planned for the following year. These are important indicators of the progress being made and the likelihood of achieving the overall project goals.

Principal investigators are required to develop a project "exit strategy," that describes how they envision the successful outcome of their LDRD project (e.g., what outcome is needed to gain programmatic support or establish a new capability of interest to an external sponsor). Progress towards this exit strategy is also evaluated, which often evolves during the course of the project.

High-level overall impact of LDRD at the Lab (including self-studies):

LLNL has a strong program in place to track LDRD performance metrics. The Lab tracks publications, citation, patents, records of invention, copyrights, R&D 100 awards, and collaborations during and after project execution (collaborations are typically not tracked after project completion) t. Many of these output metrics, such as patents, copyrights, and R&D 100 awards, are effective long-term impact metrics. In particular, a significant fraction of the Lab's approximately $10 M in annual royalties is derived from six licenses attributable to LDRD or follow-on research from LDRD. These companies were started in the 1980s and 1990s.

LLNL is striving to improve tracking of long-term LDRD impact. The POCs are interviewing selected PIs following project completion as an initial step. LLNL is putting in place a systematic process to survey PIs over the longer term following LDRD project completion.

Detailed examples of processes to track impacts through posters and deep dive into selected projects

Plutonium material properties: Measurement of the fundamental properties of plutonium are an important element of the Stockpile Stewardship Program. In particular, the LLNL Weapons and Complex Integration (WCI) Directorate requires improved knowledge of plutonium equation of state, strength, and material structure at high pressures. The National Ignition Facility (NIF) at LLNL is well suited for these complex measurements. Multidisciplinary teams have conducted several successful plutonium experiments since 2015. These experiments built on approximately 15 years of fundamental LDRD work, and over 30 individual LDRD projects, in areas such as target fabrication, diagnostic technique development, and compression physics. Many of these techniques were successfully developed in LDRD-funded experiments conducted with carbon, iron, aluminum, and other elements. These experiments yielded material property and structure data at pressures as high as 50 million atmospheres- similar to the pressures at the center of large exoplanets. This LDRD work, published in Nature and other leading journals, has had a major impact in the condensed matter and planetary sciences communities, as well as clear mission impact.

Biosecurity: LLNL has an active biosecurity program, with a focus on countering chemical and biological threats, particularly the natural, accidental, or intentional introduction of pathogens or toxins. LDRD is vital to this effort as it develops innovative technologies that are often commercialized and put into broad use. The Cepheid portable real-time DNA analyzer, developed over 20 years ago and used by the US Postal Service and others to detect anthrax, is an outstanding example. More recently, LLNL has developed the biological identification method based on information encoded in proteins, specifically those extracted from a human hair. This has a number of advantages, including the fact that proteins are more robust than easily damaged nuclear DNA. Other LDRD advances enabling applied program success include DNA micro-arrays and development of the microdroplet PCR (polymerase chain reaction) technique. DNA micro-arrays greatly enhance the speed and accuracy of agent detection, improving forensics, diagnostics, and wound infection treatment. The microdroplet PCR technique enables the time to reproduce millions of copies of DNA from approximately an hour to minutes, dramatically enhancing point of care and emergency treatment as well as applications in the agricultural industries.

Advanced Manufacturing and Architected Materials – This LDRD portfolio focusses on specializing advanced manufacturing improvements, such as 3D printing and enhanced material design and qualification using modeling and simulation, to develop materials with improved performance characteristics that can be fabricated more rapidly at lower costs. LDRD projects focused on developing and demonstrating processes that revolutionize the manner in which LLNL meets current and anticipated future customer needs. Order-of-magnitude improvements with respect to fabrication footprint, costs, and schedule have already been provided to several LLNL programs. In addition to attracting, retaining, and nurturing the workforce (>40 postdocs, >12 new early career, >60 summer interns), this portfolio has led to a significant number of publications (over 70), patents (over 50), awards (the Defense Program Award of Excellence), CRADAs (10), and strategic collaborations (including a new building in the Livermore Valley Open Campus to facilitate future open technology transfer activities).

High Performance Computation – This LDRD portfolio advances a critical LLNL core capability that includes high performance computing, computational mathematics, and data science. Remaining at the forefront of this technology is critical to LLNL's ability to accomplish many of its missions. SI projects within this portfolio typically address anticipated future lab-wide programmatic challenges, such as preparing for Exascale Computing Project and variable precision computing. ER projects address gaps identified by staff within this discipline. This portfolio has produced a significant number of publications and awards (e.g. R&D100 and Gordon Bell Prizes). In addition, the science associated with R&D is essential for attracting and retaining staff from this 'high demand' field. Finally, the impact of this portfolio can be assessed by the manner in which results have influenced technology development within and external to LLNL. It has yielded products which are used across the Lab, the DOE complex, and industry.

Posters- The committee had the opportunity to view 11 posters covering innovative research that exploit the core disciplines of the lab and with potential impact on the missions of the Lab. While most were Exploratory Research, others were Lab-Wide projects, with some starting as a Feasibility Study. The posters were hosted by the PI of the project, joined by a postdoc, a group of enthusiastic scientists and engineers. All of the posters clearly articulated the scientific and technical challenges, the accomplishments to date, and the prospective impact of the LDRD-funded research.

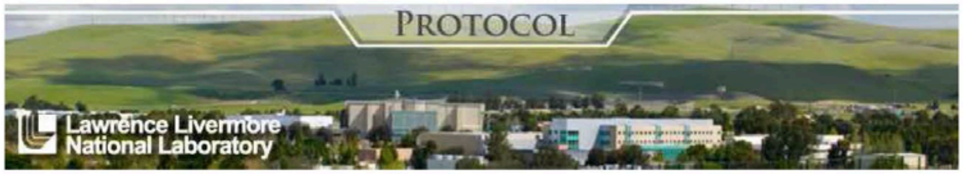
Key observations from the visit

1. *LDRD is essential to maintaining the Lab's ST&E base.* Several decades ago, LLNL national security programs supported baseline funding in the disciplines. However, much of this funding has now disappeared or been shifted to shorter-term programmatic efforts. The Lab now uses LDRD to conduct the longer-term fundamental research aimed at developing the novel new ideas and techniques that experience demonstrates will be key to addressing future national security challenges.
2. *LDRD is essential to attract and retain a high-quality LLNL workforce.* LDRD has supported over 50% of the postdocs at LLNL over the past 10 years. In fact, the fraction of postdocs supported by LDRD is often in the 70-90% range.
3. *LLNL's strategic approach to management of its LDRD research portfolio is highly effective.* LLNL manages their LDRD program to both support key core competencies required for all missions, and identify promising new programmatic thrusts that leverage these

competences. The portfolio also devotes a fraction of resources (the lab-wide program) to individual investigator driven pursuit of the best technical ideas in any area. This strategic approach allows the Lab to "skate where the puck is going." Strategic management of the LDRD portfolio enables the Lab to be a first-rate scientific institution that is also capable of quickly and effectively responding to complex, applied national security challenges.

4. *LLNL has a number of best practices that other Labs should consider adopting within their LDRD program.* These include:
   - The designation of a "lead reviewer" for all proposals with duties beyond simply reviewing the proposal. The lead reviewer is also responsible for meeting with the PI, preparing the PI for oral presentation, and in general managing the proposal throughout the review process. For successful proposals, the lead reviewer also is heavily involved in follow-on reviews and impact assessment, bringing deep familiarity with the proposal to both proposal evaluation and execution.
   - The designation of "LDRD POCs" within the major Lab directorates. The POCs play a critical role in ensuring program integration in all areas of the LDRD program, including in particular LDRD portfolio management, the development and review of proposals, and ongoing assessment of funded projects.
   - The requirement that every proposal develop an exit strategy, which could evolve over the course of the project to maximize impact. This helps maintain a strategic focus for the entire program and avoids developing a set of researchers exclusively reliant on LDRD for long-term support.
   - Establishment of an LDRD working group with other NNSA labs. This effort, performed in conjunction with the LLNL DOE/NNSA site office, promotes collaboration between the Lab and enhances efficiency of the national LDRD program.

LLNL has a strong program in place to track LDRD performance metrics (see "Processes for evaluating impact of LDRD against goals and Lab objectives" above). Planned efforts by LLNL to enhance on-going processes for collecting metrics associated with LDRD programs should better allow them to monitor the long-term impact of LDRDs and demonstrate their success. LLNL should discuss these efforts with the other DOE Labs, possibly within the LDRD working group discussed above.



DRAFT AGENDA

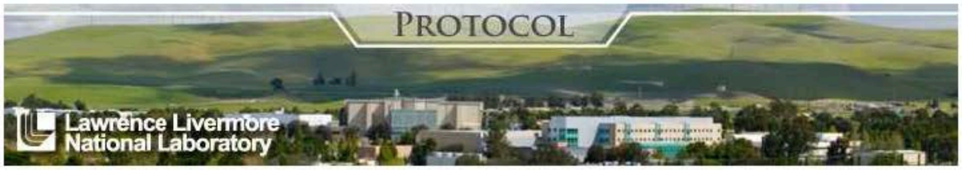
Advanced Scientific Computing Advisory Committee (ASCAC)
Laboratory Directed Research and Development (LDRD)
Independent Review Committee

Thursday-Friday, January 5-6, 2017

Thursday, January 5, 2017

7:35 a.m.	*Arrival, Badging, and Caravan to Bldg. 481*	Westgate Badge Office Met by Michele M. Morris, Protocol
7:50 a.m.	*Hospitality*	All Bldg. 481, 2nd Floor Lobby
8:00 a.m.	Meeting with the Livermore Field Office (LFO)	LFO TBD Committee Members Bldg. 481, Rm. 2004
8:30 a.m.	Welcome and Lawrence Livermore National Laboratory (LLNL) Overview	By Invitation William H. Goldstein Bldg. 481, Room 2004
9:15 a.m.	LDRD Overview and Processes	Rokaya Al-Ayat
10:00 a.m.	Executive Session	Martin Berzins, Chair Independent Review Committee
10:25 a.m.	*Break*	All
10:45 a.m.	Discussion with the Laboratory Science and Technology (S&T) Council	Laboratory S&T Council LDRD Points of Contacts Bldg. 481, Room 2005
12:15 p.m.	Lunch	Committee Laboratory S&T Council LDRD Points of Contacts Bldg. 481, 2nd Floor Lobby
1:15 p.m.	Discussion with LDRD Points of Contacts	LDRD Points of Contacts
2:00 p.m.	Discussion with Chairs of the LDRD Review Committees	LDRD Committee Chairs

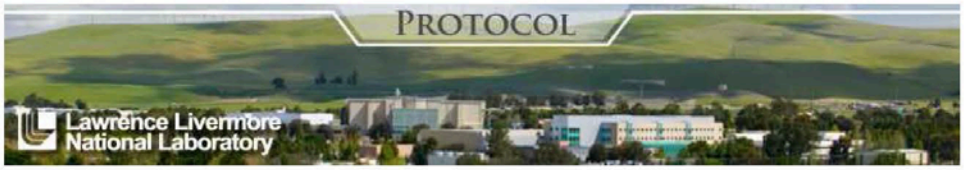
Host:	William H. Goldstein, Director, Lawrence Livermore National Laboratory
Technical Host:	Rokaya Al-Ayat, LLNL LDRD Director
Protocol:	Dustin W. Riggs, (925) 422-5780, Cell: (925) 579-4028, E-mail: riggs4@llnl.gov Barbara A. Jackson, (925) 423-1689, E-mail: jackson2@llnl.gov
Clearance:	Unclassified
Attire:	Business Casual
Agenda Date:	January 3, 2017



ASCAC LDRD Independent Review **Page 2**

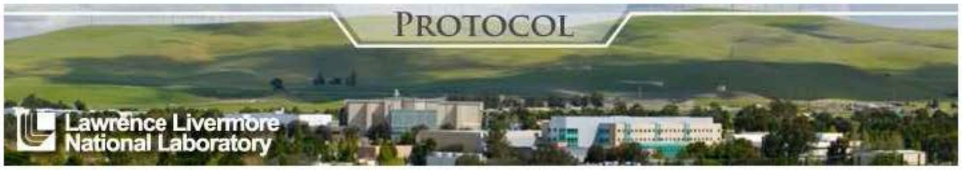
Thursday, January 5, 2017 *(Continued)*

2:45 p.m.	*Break*	All
3:00 p.m.	Architected Materials Initiative	Christopher M. Spadaccini
3:45 p.m.	LDRD and Pu Science Experiments	Tom Arsenlis Kerri M. Blobaun Bldg. 481, Room 2005
5:00 p.m.	Executive Session	Martin Berzins, Chair Independent Review Committee
5:45 p.m.	*Caravan to Bldg. 471, Central Cafeteria*	All
6:00 p.m.	Poster Session and Reception	Poster Presenters and Management
7:00 p.m.	Dinner	By Invitation Poster Presenters, LDRD Principal Investigators, Senior Management Bldg. 471, Central Cafeteria
8:30 p.m.	*Adjourn and Depart Laboratory* *(Exit LLNL East Gate Entrance)*	



Friday, January 6, 2017

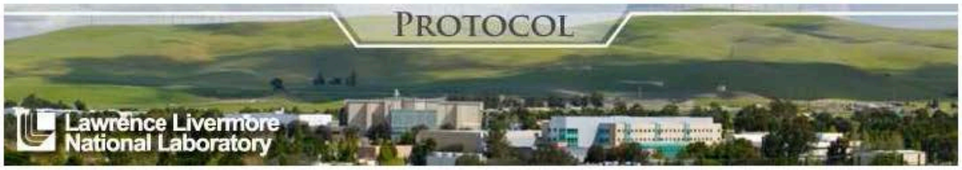
8:00 a.m.	*Arrival and Hospitality*	All Bldg. 481, 2nd Floor Lobby
8:30 a.m.	High Performance Computing, Cyber Security and Date Science	James M. Brase Lori A. Diachin Bldg. 481, Room 2005
9:30 a.m.	LDRD Impacts in the Biosecurity Program	David J. Rakestraw
10:30 a.m.	*Break*	All
11:00 a.m.	Cooperative Constellations: Resilient, Persistent and Flexible Satellite System	Michael J. Pivovaroff
	Breakout for Classified Discussion *(Jolie A. Cizewski, Christine A. Chalk, Beverly A. Ramsey, Joy L. Rempe)*	
11:15 a.m.	Working Lunch: — Concurrent Classified Discussion	Christopher M. Spadaccini Tom Arsenlis Everett W. Wheelock James M. Brase David J. Rakestraw Bldg. 381, R2206
11:45 a.m.	*Lunch*	All Unclassified Participants Bldg. 481, 2nd Floor Lobby
12:30 p.m.	Executive Session	Martin Berzins, Chair Independent Review Committee
1:30 p.m.	*Adjourn and Depart Laboratory*	All



Poster Session

Thursday, January 5, 2017
Central Cafeteria, Bldg. 471
6:00 p.m. – 7:00 p.m.

Project No.	PI	Co-I	Poster Title
13-LW-076 16-ERD-041	Felicie Albert	Nuno Lemos	Betatron X-ray Radiation from Laser-plasma Accelerators: Characterization and Development of a New Probe for High-energy-density Science
15-LW-074	Michael Bagge-Hansen	Sergei Kucheyev	Freeze Drying of Aerosols: Ice Templating of Nanoporous Metal Particles
15-ERD-046	Laura Berzak Hopkins	Andrew Ratkiewicz	Development and Qualification of a Single-shock Platform for Activation Studies with a Prompt Source of Fast Neutrons
14-ERD-038	Karis McFarlane	Ate Visser	Wetlands as a Source of Atmospheric Methane: A Multiscale and Multidisciplinary Approach
13-ERD-025	Roger Pearce	Geoffrey Sanders	Processing Massive Scale-free Graphs on Advanced High-Performance Computing Architectures
14-ERD-013	Jacob Schroder	Rob Falgout	Parallel Time Integration for Exascale Computing
11-FS-013 15-ERD-015	Nicolas Scielzo	Kay Kolos	Improving Beta-decay Studies for Fundamental Science and Applications
14-LW-077	Maxim Shusteff	Erika Fong	Continuous Automated Long-term Viral Culturing Platform for Infectious Disease Therapeutics
16-ERD-035	Vanessa Tolosa	Anna Marie Belle	Understanding and Treating Brain Disorders Using Micromachined Probes
15-ERD-022	Brandon Wood	Joel Varley	An Integrated Mesoscale Approach for Predicting Ionic Conductivity in Solid Electrolytes
17-LW-035	Dawn Shaughnessy	John Despotopulos	The Superheavy Elements Discovery and Chemistry program at LLNL



Committee Members:
Martin Berzins, University of Utah (Chair)
Dawn Bonnell, University of Pennsylvania
Christine Chalk, U.S. Department of Energy
Jolie Cizewski, Rutgers State University, New Jersey
Karsten Heeger, Yale University
Tony Hey, University of Washington
Christopher Keane, Washington State University
Samuel Kessler, TBD
Beverly Ramsey, Desert Research Institute
Karin Remington, Computationality
Joy Rempe, Rempe and Associates, LLC

LLNL Invitees/Speakers:
Rokaya Al-Ayat
Tom Arsenlis
Kerri M. Blobaum
James M. Brase
Jeffrey D. Bude, LDRD POC
Kristin L. Croteau
Lori A. Diachin, LDRD POC
Patricia K. Falcone
Glenn A. Fox
Eric E. Gard, LDRD Lab-wide Committee Chair
William H. Goldstein
Constantin Haefner, LDRD Committee Chair
Denise E. Hinkel, LDRD POC and LDRD Committee Chair
Anantha Krishnan
Kristen S. Kulp, LDRD Committee Chair
John M. May, LDRD Committee Chair
Dennis P. McNabb, LDRD Committee Chair
Michael J. Pivovaroff
David J. Rakestraw
Robert M. Sharpe, LDRD POC
Henry F. Shaw, LDRD POC
Christopher M. Spadaccini
Gregory J. Suski
Anthony W. Van Buuren, LDRD Committee Chair
Charles P. Verdon
Bruce E. Warner
Amy M. Waters, LDRD POC
Peter K. Weber, LDRD Committee Chair
Everett W. Wheelock
Jeff Wisoff

Oak Ridge National Laboratory – Oak Ridge Tennessee

Introduction

Oak Ridge National Laboratory (ORNL) is the DOE's largest and most diverse multi-program Lab in science and energy research. This Laboratory's diverse capabilities span a broad range of scientific and engineering disciplines, enabling the Laboratory to explore fundamental science challenges and to carry out the research needed to accelerate the delivery of solutions to the marketplace. ORNL supports DOE's National missions of:

- **Scientific discovery**: Assembling teams of experts from diverse backgrounds and equipping them with powerful instruments and research facilities to address compelling National problems;
- **Clean Energy**: Delivering energy technology solutions for energy-efficient buildings, transportation, and manufacturing, while studying biological, environmental and climate systems to develop new biofuels and bioproducts;
- **Security:** Developing and deploying "first-of-a-kind" science-based security technologies to make the world a safer place.

ORNL has an annual budget of approximately $1.5B, about 4,750 employees and hosts some 3,200 research guests annually. It hosts the Nation's most diverse energy research portfolio, the largest materials research portfolio, the world's most intense neutron source and a world class research reactor. ORNL also is the lead organization of some of the major DOE programs, such as US ITER (part of a global fusion energy research program), and hosts leadership class scientific computing resources for the DOE research community. Its annual productivity and scientific output are represented, for example, by some 1,900 journal articles, 185 invention disclosures, and 83 patents issued in FY 16.

ORNL's overall R&D program addresses a broad variety of programs that are aligned with DOE missions and National needs. The breakdown of the ORNL activities in major categories of funding as provided in the Lab overview is shown for FY16 in Figure 6.

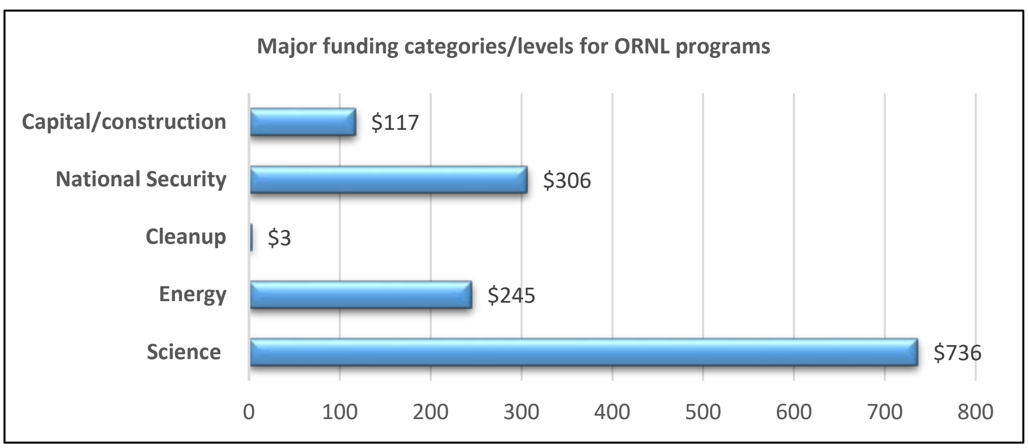


Figure 6: Funding levels for ORNL programs in FY16, in millions of dollars.

The organizational structure for the Lab is shown in Figure 7, and identifies the Lab divisions and the Associate Lab Directors, who play a fundamental role in the management process of the ORNL LDRD program, as described in subsequent sections of this report.

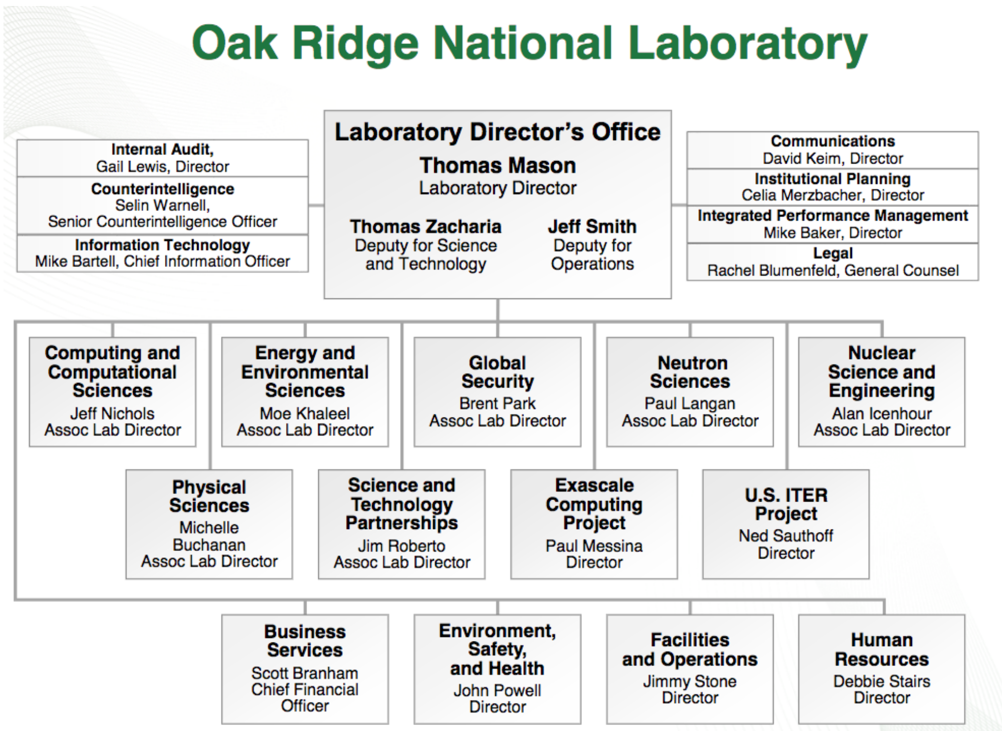


Figure 7: ORNL Laboratory Organizational Structure

We would like to note that ORNL submitted a great deal of information in support of the review, including detailed written answers to the Committee's questions sent in advance, and links to various internal reports, including their self-assessment of the LDRD program which was completed in early 2016. They also contributed to the success of our review process by arranging a detailed agenda for a full day, including presentations and time for in-depth discussion and inquiry, including informal discussions at an informal poster session.

Overview of LDRD at ORNL

LDRD is an essential component of the planning and investments in the future directions of ORNL, allowing the Lab to explore innovative science and technology to meet DOE missions. The LDRD program is administered following standard practices for award funding. It includes a competitive solicitation with clearly articulated goals and process for the selection of projects. The execution of this process is documented in ORNL's Standards Based Management System (SBMS), published in the annual call for proposals to the Director's R&D Fund, and maintained on the Lab's overhead investment system webpage. This is an internal resource for the LDRD project management team. All activities in this LDRD program are consistent with objectives of DOE Order 413.2C.

Elements of ORNL's LDRD Program: ORNL's LDRD program is designed around three complementary components. The Director's R&D Fund is the largest component of the Lab's LDRD program with $35M out of $44M, followed by the Seed Money Fund ($5.6M) and the Named Fellowship Fund ($3.6M). With this FY16 budget, ORNL supported 105 R&D projects, 60 seed money projects and 22 named fellowships.

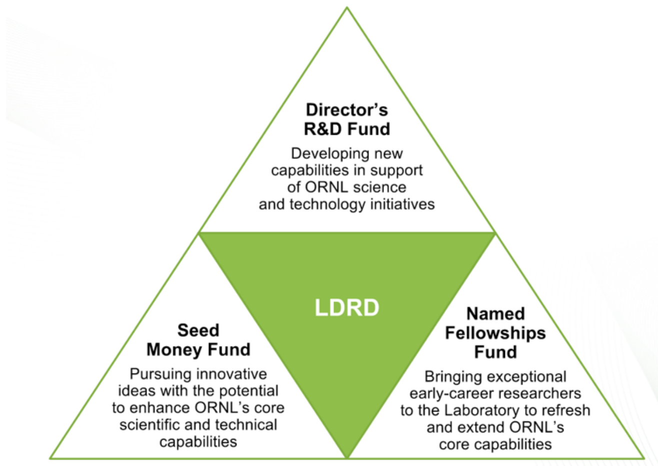


Figure 8: Elements of the ORNL LDRD Program

Organization: Overall responsibility for the LDRD program lies with the Lab Director. The Deputy Director for Science and Technology (DDST) oversees and coordinates the implementation and approves all projects recommended for funding. The supervision of LDRD policy and procedures including the oversight of project reviews, selection and recommendation for funding is with the Director of the Office of Institutional Planning (OIP). The LDRD Program Manager manages and administers all LDRD processes and ensures compliance with DOE Order 413.2C. The Associate Lab Directors (ALDs) serve as the initiative leaders guiding LDRD investments and participate in all aspects of the LDRD process.

Planning: The LDRD solicitation is fully integrated into the Lab's strategic planning process and the Lab agenda guides the LDRD planning process. The R&D priorities are identified to support ORNL's major S&T initiatives. This is driven by initiative plans documented in the Lab agenda, which itself presents a 10-year vision together with 3-year strategic outcome goals, and performance objectives for the current FY. The planning process is further informed by the ORNL Big Science Questions (BSQ) process that was developed following a recommendation from the FY15 ORNL Science Advisory Board review meeting. The BSQ process is a bottom-up (S&T staff-driven) approach for informing LDRD initiatives, institutional strategy and business planning.

Goals and Objectives: Through their planning processes, the Lab pursues several strategic objectives: excellence in science and technology, excellence in mission support, and excellence in community engagement.

The aim is to deliver scientific discovery and technical breakthroughs in support of DOE missions in clean energy and global security, create economic opportunity for the Nation, sustain and improve ORNL's ability to serve the needs of DOE and the Nation through responsible stewardship, and to be viewed by neighbors within the region as a highly-valued partner.

Seed Funding: Seed Funding is used at ONRL to support smaller projects and innovative ideas that may lead to larger initiatives. Seed funding is one of the key mechanisms that support innovative ideas with the potential to enhance ORNL's core scientific and technical competencies. It also supports new approaches that fall within ORNL's distinctive capabilities but outside the more focused research priorities of the major initiatives. Often seed money is a key source for innovations that lead to R&D 100 awards. One such example is the development of band excitation scanning probe microscopy. The R&D for this technique was initiated by a Wigner Fellow with Seed Money and led to a R&D 100 award.

Workforce Development and Personnel:

Named Fellowships supported through LDRD are a key element in attracting exceptional talent and personnel to the Lab. The expansion of the Named Fellowship Fund resulted from a strategic decision in FY13 to increase budgets for early career staff appointments. In FY15 this program was broadened to include the Russell Fellows Program with emphasis on diversity. At present the Lab supports approximately 24 fellows every year through the Wigner, Weinberg, Householder, and Russell programs. The investments in young high-potential staff has had a lasting impact on the development and innovation at the Lab. Several distinguished group leaders, division directors, and members of the university leadership were recruited and retained through the Named Fellowship program. Since 2007, 56% of Wigner Fellows (20 out of 36) have remained at ORNL as R&D staff.

Another important element of the workforce development and the inclusion of personnel in the planning and strategic direction of the Lab is the engagement of early-career staff in LDRD funded projects. Of the 429 PhD principal investigators and co-investigators on FY17 LDRD projects, 46% are early career staff within 10 years of their PhD.

LDRD support has also been used to enable strategic hires into the Lab to build and strengthen key scientific areas. Since 2005 there have been 26 strategic hires with a 96% retention rate. These hires are in significant leadership positions and have authored 95 highly cited (>100 citations) publications.

It should be noted that the process for proposal development, selection and subsequent performance tracking includes a deliberate mentoring component for early stage investigators. Mentoring and coaching on proposal development, proposal presentation, and proposal refinement is provided by the Office of Institutional Planning and the Associate Lab Directors for all LDRD applicants.

Processes for Determining LDRD Funding Levels at Laboratory Level

At the Lab level, ORNL maintains an annual senior leadership process for strategic planning, including prioritization of initiatives and funding allocations. This cycle includes a leadership retreat, which is followed by a regular process of allocations. Through the past 10 years, this process has resulted in several strategic funding priority decisions, most recently to increase the allocation to LDRD from 3.1% (FY16) to 4% (FY17). The Leadership Team carefully considers

LDRD allocations in its overall strategic process to maximize the benefit to the research and development priorities of the Lab.

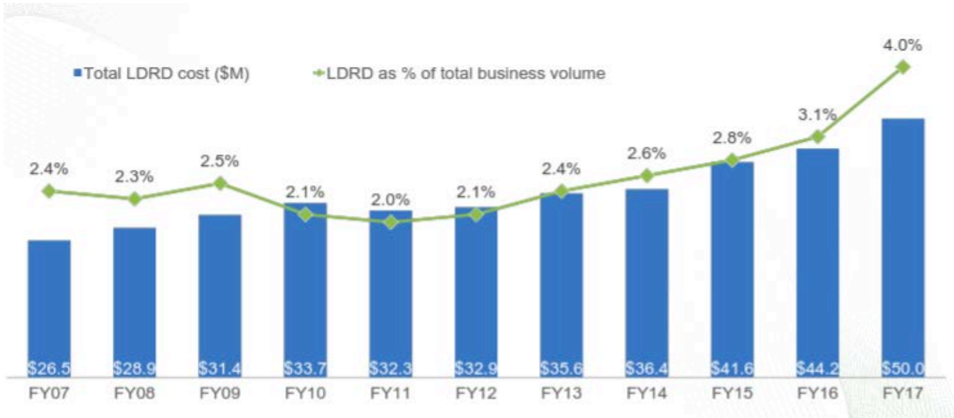


Figure 9: LDRD budget at ORNL from FY07-17.

Processes for Proposal Solicitation, Review and Selection

The ORNL LDRD processes are well structured and documented. The Director's R&D, Seed Money, and Named Fellowships Funds share common requirements for review and selection. The Guidelines for proposal format and content, technical review criteria, and selection criteria are maintained in ORNL's Standards Based Management System (SBMS) and provided to prospective principal investigators (PIs), reviewers, and committee members. All proposals undergo technical reviews by subject matter experts. The selection committees (composed of technical staff and program managers) make recommendations to ORNL's Deputy Director for Science and Technology (DDST) and selection committee chairs brief committee members on their roles and responsibilities. The DDST considers committee recommendations, selects projects for funding, and submits to DOE for concurrence. The review and selection of proposals follows well established criteria in two categories (review and selection) that are advertised in the call for proposals. The review and selection process ensures that the proposed LDRD research is relevant to ORNL's strategic goals and long-term vision. Projects presented to the visiting committee had a clear connection to the 3-year strategic plan and fit into the 10-year vision of the Lab. It was clear that the LDRD program and the research supported is guided by the strategic lab plan and the vision for the direction of the Lab.

Review and Selection: Once proposals are submitted, the review and selection of LDRD projects is performed by several selection committees that provide critical input throughout the process.

<u>Directors R&D Funds:</u> For the Director's R&D Fund the Initiative Review Committees (IRCs) provide technical and strategic recommendations. The IRC membership consists of chairs who are nominated by ORNL Associate Laboratory Directors (ALDs) and approved by the DDST, and members who are nominated by ALDs, reviewed by Director of Institutional Planning (DoIP), and approved by DDST. Members include technical staff at all ranks from early career to Corporate Fellows and program managers. About 1/3 of members roll off the IRC reach year.

<u>Seed Money Fund</u>: The selection committee of the Seed Money Fund is chaired by the LDRD Program Manager and includes two Members from each R&D directorate to ensure that the expertise spans the technical breadth of ORNL. The Members are nominated by the ALD and

approved by the DDST. The term of service for Members is two years with a staggered roll-off to maintain continuity. Serving on the Seed Money Fund Committee is widely considered a development opportunity for early career staff and the Lab uses this opportunity for the professional growth and training of its staff.

Named Fellowship Selection Committee: This committee conducts Fall and Spring recruiting campaigns to identify promising candidates, works closely with sponsoring divisions to ensure appropriate mentoring and career development plans are in place, reviews each candidate's LDRD proposal, and eventually makes hiring recommendations to the DDST. The Named Fellowships are critical to attracting talented early-career staff and therefore the selection committee plays a critical role in securing the future talent and leadership of the Lab.

Initiative Review Committee (IRC)s: IRC Chairs to help oversee the Directors' R&D Fund Initiatives, which fall in areas such as:

- Transformational nuclear science and technology
- Computer science and math for exascale computing
- Next generation data, modeling and simulation for neutron science
- Materials innovation: from Atoms to Function
- Integrated studies of complex biological and environmental systems
- Transformational energy science and technology
- Quantum computing: quantum materials and interfaces
- Cyber security and resilience
- Discovery science and innovation

The IRC chairsplay a major role in the execution of ORNL LDRD program. Their role is summarized in Figure 10.

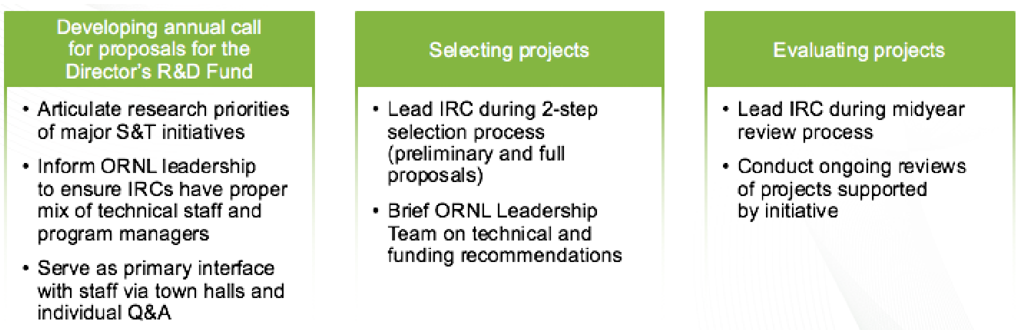


Figure 10: Role of IRC chairs in the execution of the ORNL LDRD program

Cycle Flexibility: One of the central goals of the LDRD program is to develop and capitalize on new ideas. To provide such flexibility, the DDST reserves some funding for out-of-cycle projects. This allows ORNL and the PIs to position themselves in a changing scientific and technical landscape and to capture emerging opportunities. This special avenue follows the same strict principles of review and selection as the standing annual processes of the Lab. This process is illustrated in Figure 11.

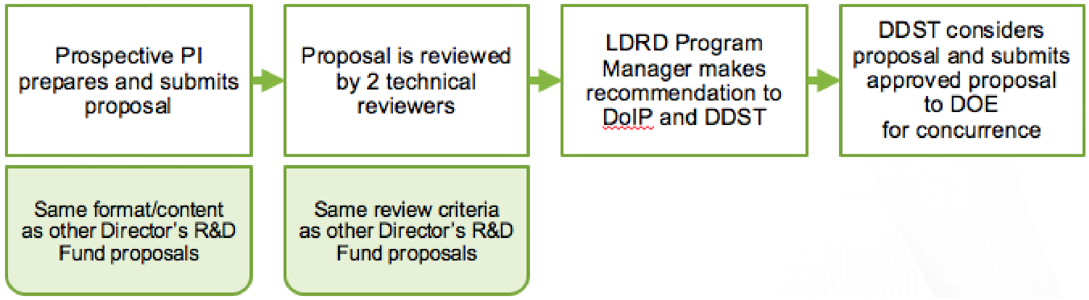


Figure 11: Review and selection of out-of-cycle LDRDs.

Self-Assessment: As part of its recent self-assessment process (FY15, report released in March 2016), ORNL has quite thoroughly documented its current processes for strategic direction and prioritization, allocations, proposal solicitation, selection, and performance monitoring. We found during our visit that staff, from early career to senior leadership, are all very familiar with the process, and find that it is transparent, well-reasoned, fair, and well-implemented.

Software Assisted Tracking: A featured tool used at ORNL in these processes is their Laboratory Overhead Investment System (LOIS), which is the primary electronic interface for Principal Investigators (proposal submission), Reviewers (documentation of reviews) and Approvers (documentation of approval). This system has been in use for many years, and provides a historical record of the LDRD program which can be pulled from to support retrospective analyses.

Processes for Progress Monitoring

ORNL maintains a regularized and thorough process, documented in their Standards Based Management System, for monitoring progress of LDRD projects. This includes an LDRD review before the award, a mid-year review by LDRD staff and the review committee with progress reports and presentations, and a year-end summary in LOIS. The project management of each award is performed in RESolution. Two major results tracked for each award are publications and the integration of the activities into future projects.

All Investigators from Post-Docs to Early-Career, to Senior Investigators who the visiting team encountered were clearly aware of the process and found it to be a substantial and worthwhile process. An example of the process is reflected in Figure 12. The details in each step may vary slightly but each project follows the same basic structure across all divisions.

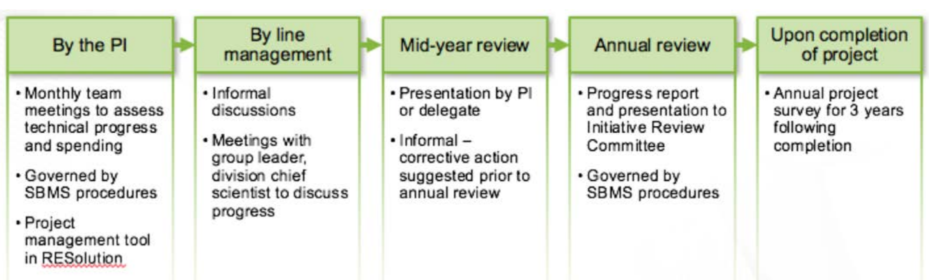


Figure 12: Annual Cycle of review and progress monitoring for each LDRD project.

The success of each project is evaluated against and tracked along several key elements including:

- Education and training
- Visibility within the community
- Presentations
- Publications in top journals
- Research outcomes
- Follow-on funding

The Seed Money Fund review process is tailored to the rolling selection process of the program. In this case, the Seed Money Committee Chair conducts reviews with the project PI and team, whereas line management conducts ongoing assessments and provides mentoring of the project PI and team.

Several examples were presented at the site review, including description of the tangible outcomes and the success of each project, with open discussion of each. One metric for the monitoring and the success of each project is the use and development of ORNL's core capabilities. It was demonstrated at the review that each project can map itself onto one or more of the core capabilities of the Lab, and routinely does so as a matter of process. Connections to ORNL's S&T initiatives were also highlighted as appropriate.

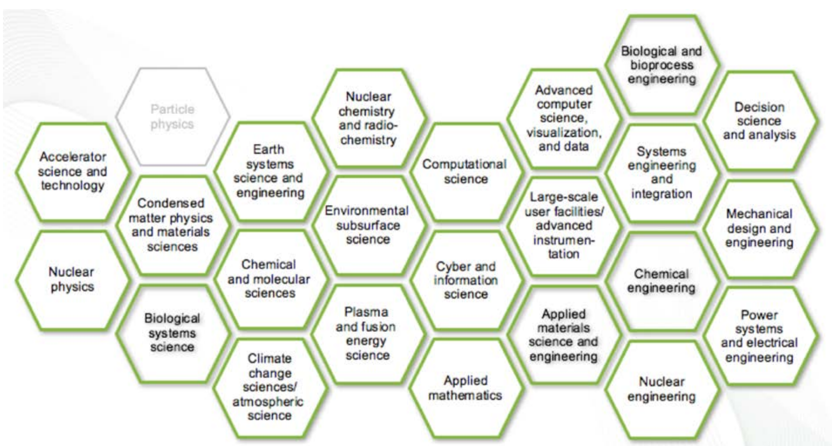


Figure 13: The 23 core capabilities of ORNL. All core competencies except for Particle Physics are represented at ORNL.

Processes for Evaluation of Impact

ORNL annually assesses the success and impact of its LDRD program, and maintains ongoing progress reports from individual projects as well as roll-ups of indicators into specific program areas. The evaluation of impact and success take place at three levels:

- Evaluation of <u>*project*</u> success and impact;
- Evaluation of <u>*program*</u> success;
- Exploitation of LDRD success for the <u>*mission and vision*</u> of the Lab, including:
  - Focusing on research priorities of ORNL S&T Initiatives
  - Sustaining and extended ORNL core capabilities

- Enhancing ONRL’s capability to address DOE/NNSA missions
- Enabling high-risk, high value research on forefront S&T.

In its annual assessment, ORNL assures consistency with DOE Order 413.2C and documents program level performance indicators. The annual PI project summaries and surveys form the basis of the required ORNL annual and self-assessment reports. Additional tools that are available to the Lab management include the monthly investment reports and project management tools. Project summaries include narratives of scientific/technical progress, mission relevance, and S&T productivity (publications, presentations, intellectual property, etc.) and are reviewed by Division Directors and the LDRD Program Manager.

In addition, the annual survey and data gathering process provides publication data, information on intellectual property such as invention disclosures, patents and copyrights issued, and workforce development. This annual process collects and summarizes a wealth of data on:

- Publication data (total publications, citations, highly cited publications);
- Intellectual Property (invention disclosures, patents issued, copyrights issued);
- Workforce Development (students, postdoctoral researchers, new hires);
- Program Development (follow-on funding);
- Honors and Awards;
- Programs benefitting from the investment (both DOE and other federal agencies).

The data from this annual survey is reviewed by the LDRD Program Manager, the DDST, and the Lab Director. One of the key features and strength of the ORNL system for evaluating project success and impact is not only the gathering of data but the process for reviewing and evaluating the data on a regular basis, and acting upon the information in each new planning cycle.

Software Tool Support: To manage its LDRD program ORNL has developed tools for real-time reviews of individual LDRD projects and the overall program.

<u>The Laboratory Overhead Investment System (LOIS</u>) is the primary electronic interface for PIs (proposal submission), reviewers (documentation of reviews), and approvers (documentation of approvals).

<u>RESolution, a scientific productivity program used at ORNL, has recently implemented a project management</u> tool that provides both project-level and program-level evaluation data. Midyear reviews are informed by midyear progress reports and the RESolution project management tool, which enables PIs, line managers, IRC chairs, and the LDRD Program Manager to monitor project progress and accomplishments on a continuous basis. PIs create project files by importing data from LOIS and specify project milestones and spending profiles. PIs are expected to update project files monthly. Additionally, the ORNL LDRD program uses a publication discovery, verification and curation tool, which assists in the ongoing effort to track one key measure of impact: scientific publications. ORNL presented a demonstration of both tools to the 2016 LDRD Annual Meeting, and has been contacted by other Labs to share the software best practice.

It is interesting to note that ORNL has recently been working toward the adoption of a commercial-quality software package (Tableau) to allow for exploration of this data in a dynamic fashion, aiming to better understand trends and patterns in their portfolios. This has the potential to become another "best-practice" that they can share with the other Laboratory LDRD programs.

Examples of Processes through Deep Dive into Selected LDRD Projects and Programs

Named Fellowships: One of the signature programs of the ORNL LDRD program is the Named Fellowship Funds, used to attract exceptional talent to the Lab. As part of the site review, the Subcommittee learned about the multi-faceted impact of this program on the ORNL personnel and workforce. With the decision to increase budgets for early career staff appointments in FY13 and the introduction in FY15 of the Russell Fellows program with emphasis on diversity, ORNL has positioned itself to attract a diverse and inclusive workforce and reinvigorate its scientific talent and leadership team. From the examples presented, it is evident that these investments in high-potential staff pay long-term dividends for the Lab. For example, 1979 Wigner Fellow Nancy Dudney is now a group leader with over 177 publications. She is a Fellow of the Electrochemical Society a UT-Batelle Corporate Fellow and Distinguished Inventor. She holds 4 R&D 100 Awards and has contributed to the mission of the Lab for over 30 years. 2007 Wigner Fellow Athena Safet is a highly-published research staff member with over 211 publications, a fellow of the APS. She also received an Early Career Research Award in recognition of her research and accomplishments.

In many ways, the Named Fellowships pave the way to the future of the Lab. The named fellows are the public face representing the vision of ORNL. Combined with training, education, and mentoring, the Named Fellowships are amongst the best investments the Lab can make in the excellence of its workforce and in ensuring the future vitality and creativity of the Lab.

Project: Open Quantum System: One of the projects presented at the review was "Dissipation-Driven Quantum State Engineering" from the Computational Sciences and Engineering Division. This project addresses one of the key challenges in open quantum systems. Qbits couple to the environment resulting in decoherence. This project aims to make use of dissipative interactions as resources for universal quantum computing and engineer interactions between quantum dots and metal nanostructures for a more efficient quantum computing platform.

The LDRD-funded quantum information science (QIS) research at ORNL is an example of how LDRD funding help Lab research keep pace and look forward in a rapidly evolving field with worldwide competition. The aim is to capture an emerging opportunity while pursuing ORNL's strategic goals and long-term vision. The 3-year strategic goal is to evaluate data analytics opportunities leveraging future technologies such as neuromorphic and quantum computing to discover advanced approaches to analyze scientific data. A successful completion of this project may provide a pathway to deploy scalable computing ecosystems to sustain world leadership for DOE and perform breakthrough research in computational theory, modeling and simulation, and data analytics that utilize exascale (and beyond) computing capabilities.

Key Observations from Site Visit

- The ORNL LDRD program is a vibrant and invigorating element of the Lab's activities and critical to achieving the mission of the Lab and of DOE. It exploits innovative science and technology and develops the excellence of the ONRL workforce to meet the lab's S&T goals.

- The LDRD program at ORNL is well organized, strategically planned, carefully implemented, and transparent to participants and external observers. The structure of the LDRD, including the different programs and types of funding, is designed and optimized to meet the needs of the Lab, and to exploit opportunities in scientific and technical directions as well as to attract personnel to strategic initiatives.
- The LDRD program is essential to maintain, reinvigorate, and renew the high-quality scientific workforce and leadership team at the Lab.
- The Office of Institutional Planning and the LDRD Program Manager are thoughtful stewards of the LDRD Programs.
- Senior Leadership, Scientific Staff and Postdoctoral students find the LDRD program critical to their overall success. The combination of providing targeted shared initiatives, seed funding, and highly prized fellowships is considered a successful balance.
- The management tools used at ORNL for project tracking are among best-in-practice, and are being shared with the broader LDRD community. They are continuing to innovate in this area by investigating new tools for data analysis that will assist in portfolio analysis going forward.
- The LDRD program uses tools that will allow the long-term tracking of the impact of LDRD projects on the Lab's scientific output and its S&T goals.

OAK RIDGE National Laboratory

AGENDA

MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

ASCAC LDRD Program Review

Event contacts	John S. Neal, 865-576-8275 (office); 865-256-6762 (mobile); nealjs1l@ornl.gov Tacie R. Hall, 865-574-7852 (office); halltr@ornl.gov

Thursday, January 26, 2017

Time	Event/Activity	Lead	Attendees	Place
8:30-9:00 a.m.	Arrival and Badging	John S. Neal will meet at Visitors Center	ASCAC Review Committee Participants Dr. Martin Berzins (Chair) Dr. Jolie Cizewski Dr. Karsten Heeger Dr. Tony Hey Dr. Chris Keane Dr. Beverly Ramsey Dr. Karin Remington Dr. Joy Rempe Russell Ames – DOE	Building 5200, Visitor's Center
9:00-9:30 a.m.	Review Committee Executive Session	Martin Berzins, Chair	ASCAC Review Committee	Building 5200, Conference Center, Room 219 (Cumberland)
9:30-10:30 a.m.	ORNL Overview: Goal Setting and Funding Levels Processes • Processes for determining funding levels for the LDRD program	Thom E. Mason	ASCAC Review Committee, Thomas Zacharia, Michelle Buchanan, Alan Icenhour, Moe Khaleel, Paul Langan, Shaun Gleason, John Neal	Building 5200, Conference Center, Room 219 (Cumberland)
10:30-10:45 a.m.	Break			
10:45 a.m. – 12:00 p.m.	Strategic Direction • Processes for determining Lab-specific goals and allocation of resources among the goals	Thomas Zacharia	ASCAC Review Committee, Michelle Buchanan, Alan Icenhour, Moe Khaleel, Paul Langan, Shaun Gleason, John Neal	Building 5200, Conference Center, Room 219 (Cumberland)
12:00-12:45 p.m.	LDRD Project Selection Processes • Processes for selecting projects • Initiative Review Committee Chair Roundtable	Bobby Sumpter	ASCAC Review Committee, Thomas Zacharia, Michelle Buchanan, Alan Icenhour, Moe Khaleel, Paul Langan, Shaun Gleason, and John Neal, IRC Chairs	Building 5200, Conference Center, Room 219 (Cumberland)
12:45-1:30 p.m.	Working Lunch (Catered) and Review Committee Executive Session	Martin Berzins, Chair	ASCAC Review Committee	Conference Center Building 5200, Room 219 (Cumberland)

OAK RIDGE National Laboratory

AGENDA

MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

Event contacts	John S. Neal, 865-576-8275 (office); 865-256-6762 (mobile); nealjs1l@ornl.gov Tacie R. Hall, 865-574-7852 (office); halltr@ornl.gov

Thursday, January 26, 2017

Time	Event/Activity	Lead	Attendees	Place
1:30-2:00 p.m.	Meeting with ORNL Site Office	Martin Berzins, Chair	ASCAC Review Committee and from DOE Site Office Johnny Moore, Michele Branton, Mary Rawlins, and Randy Fair	Conference Center Building 5200, Room 219 (Cumberland)
2:00-3:15 p.m.	LDRD Poster Session	John Neal	ASCAC Review Committee and Poster PIs	Building 5200, 2nd Floor Lobby
3:15-3:30 p.m.	Break			
3:30-4:30 p.m.	LDRD Project – Deep Dive	Phil Evans, Josh Michener, Olga Ovchinnikova, and Gabriel Veith	ASCAC Review Committee, Thomas Zacharia, Michelle Buchanan, Alan Icenhour, Moe Khaleel, Paul Langan, Shaun Gleason, and John Neal	Conference Center Building 5200, Room 219 (Cumberland)
4:30-5:30 p.m.	LDRD Program Success/Impact Evaluation Processes • Processes for evaluating the success and impact of the LDRD program against Lab-specific goals and LDRD Program overall objectives over a 10-year period • Associate Laboratory Director Roundtable	Michelle Buchanan	ASCAC Review Committee, Thomas Zacharia, Alan Icenhour, Moe Khaleel, Paul Langan, Shaun Gleason, and John Neal	Conference Center Building 5200, Room 219 (Cumberland)
5:30-6:00	Wrap-up Discussions	Thomas Zacharia	ASCAC Review Committee, Thomas Zacharia, Alan Icenhour, Moe Khaleel, Paul Langan, and Shaun Gleason	Conference Center Building 5200, Room 219 (Cumberland)
6:00- TBD pm	Review Committee Executive Session	Martin Berzins, Chair	ASCAC Review Committee	Conference Center Building 5200, Room 219 (Cumberland)

National Renewable Energy Laboratory – Golden, Colorado

Agenda and summary of information provided in advance

NREL, is focused by DOE to answer to current and emerging energy challenges. From breakthroughs in fundamental science to new clean technologies to integrated energy systems that power our lives, NREL researchers are charged with transforming the way the nation and the world use energy. NREL is the nation’s premier energy efficiency and renewable energy science and technology Lab. It offers unique facilities and leadership to work with commercial, government and energy service providers through agile practices that enhance impacts in a timely manner. NREL has 13 major research programs and nearly 1700 employees. In addition, approximately 180 visiting scientists, post doctorate fellows, graduate students, interns and contractors are involved annually. The funding level for NREL in 2017 is $357 million. Of this amount, the spend on the LDRD program is expected to be $14.5M or about 4%, which is below the mandated 6% ceiling. NREL views LDRD as being of increasing importance and so has been gradually increasing its LDRD spend from about 50% of this in 2010.

NREL houses three national centers on the 327 acres at the main campus and the 305 acres at the National Wind Technology Center:

- National Bioenergy Center
- National Center for Photovoltaics
- National Wind Technology Center

NREL is the DOE National Laboratory most directly engaged between government and academic research, utility research and technology implementation, and private energy corporations. In the pursuit of these collaborations NREL utilizes the facilities listed above as well as newer research facilities that have been commissioned:

- Energy Systems Integration Facility (ESIF)
- Process Development & Integration Laboratory (PDIL)
- Integrated Biorefinery Research Facility (IBRF)

NREL performs foundational science and engineering for energy efficiency, sustainable transportation and for renewable energy sources and technologies. NREL provides knowledge for integration and optimization of energy systems. NREL works with private sector, government and partners to innovate, validate and commercialize technologies for U.S. economic growth, energy and for national security (currently 749 active partnerships). There are approximately 800 patented/patent pending technologies available for licensing. Many of these have resulted in more than 100 R&D 100 awards.

NREL has mapped its research programs across several capability sets which are:

- Analysis & System Integration
    - Advanced Computer Science, Visualization & Data
    - Biological Systems Science

- Decision Science and Analysis
- Large-Scale User Facilities
- Systems Engineering & Integration

- Innovation & Application
  - Chemical Engineering
  - Mechanical Design & Engineering
  - Power Systems & Electrical Engineering
- Foundational Knowledge
  - Chemical & Molecular Science
  - Biological & Bioprocess Engineering
  - Applied Materials
- Science & Engineering
- Advanced Computer Science, Visualization & Data
  - Biological Systems Science
  - Large-Scale User Facilities

The NREL Organization Chart is shown in Figure 14.

NREL furnished the following in advance of the site visit by the review team. These were:

- LDRD Program Overview
- Summary of LDRD Funding Levels and Program Organization
- Sample Call for Sustaining Proposals in LDRD
- NREL LDRD Procedure
- Agenda for ASCAC Review of LDRD Program
  - Welcome and Introductions
  - Review of Committee Charge
  - Overview of LDRD Process & Director's Postdoctoral Fellowship Program
  - LDRD Program Success Stories; Impact of LDRD Projects & Evaluation & "Deep Dive"
    - Bioscience & Renewable Fuels, Chemicals: Lignin Utilization
    - Advanced Materials: Perovskite S&T
    - Engineering Science and Technology: Improving Accuracy of Lidar-Based Turbulence Measurements
    - Grid Modernization: Distributed Control for Energy Systems
    - Clean Energy Systems/Decision: Power Sector Modeling
  - NREL Science Advisory Committee Interviews
  - LDRD Poster Session
  - Wrap Up

Following the review we were provided with copies of the PowerPoint slides used as well as specific answers to the questions that we posed. Much of the material in this report is a modified form of the material that reflects what the Subcommittee saw on its visit to NREL.

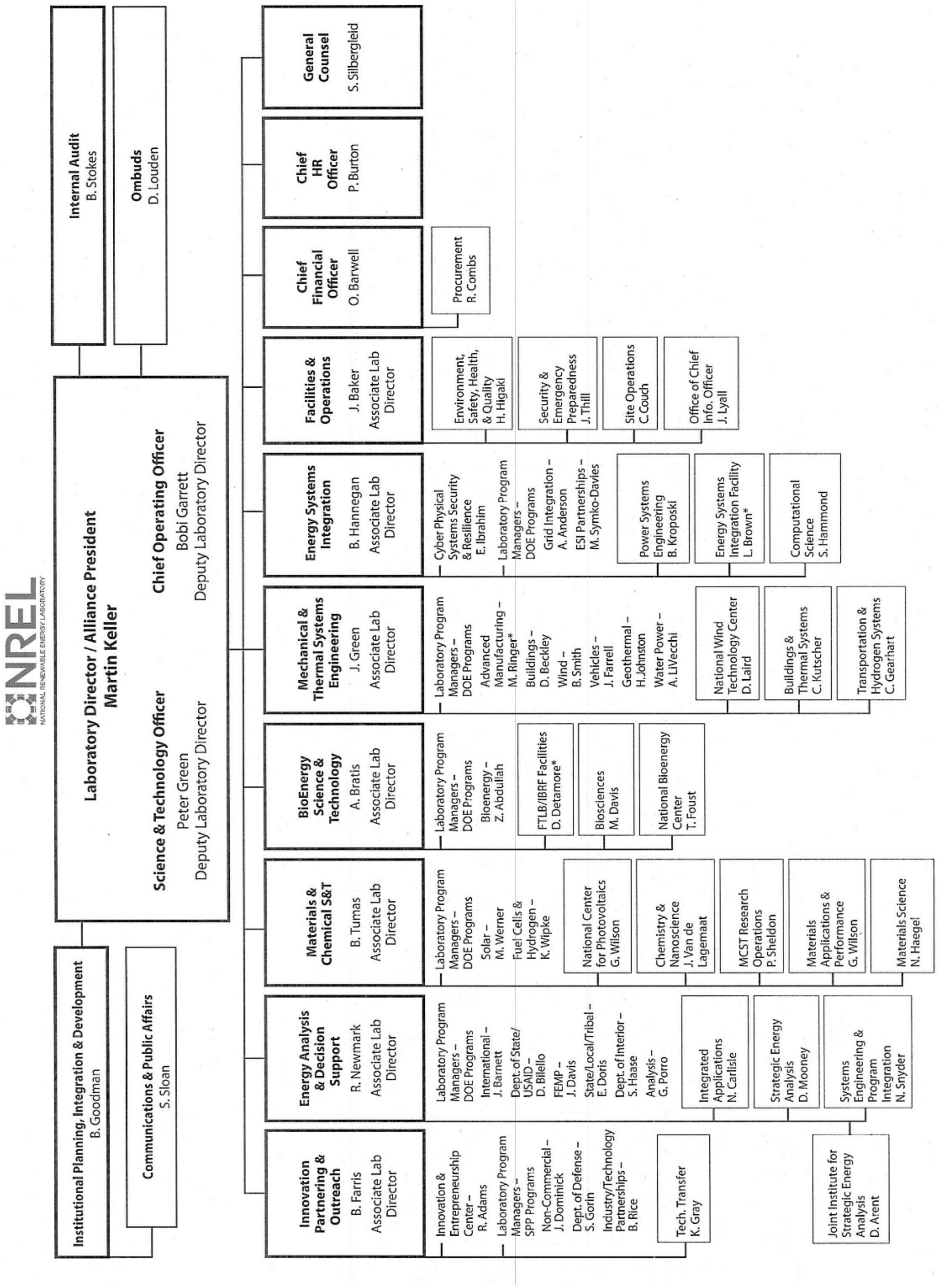


Figure 14: Organizational Structure of NREL

Strategic overview of LDRD (including Lab LDRD Office, internal organization, plans and proposed improvements).

The NREL LDRD Portfolio Management has 4 elements:

- **Transformational Initiatives** (multi-year/multi-project): Establish or reposition a unique institutional capability that will provide the basis for opening promising new areas of research that are beyond the current trajectories of DOE programs.
- **Sustaining Projects**: (generally 2 years): Enable the Lab to refresh its current research portfolio and sustain technical leadership and relevance in the programs in which it has a longstanding role.
- **Seed Projects** (less than 1 year): Develop initial data or proof-of-principle for concepts that may be proposed in FOAs or program opportunities.
- **Talent Development** – NREL Director's Fellowship Program: Attract exceptionally qualified science or engineering post docs with outstanding talent and credentials in renewable energy research and related disciplines.

NREL has vested the LDRD program within the Institutional Planning, Integration and Development Office which reports directly to the NREL Lab director. The strategic agenda for the lab addresses:

- Increase early stage research, strengthening core capabilities & establish proof-of-principle for new concepts
- Recruit and retain world class scientists and engineers
- Strengthen partnerships with leading research universities
- Maximize the impact of the Energy Systems Integration Facility (ESIF)
- Enhance technology transfer: elevate market-relevant innovation across the RNEL portfolios

NREL believes that LDRD is essential to sustaining the relevance and impact of its research to it mission. The strategy uses an annual Lab plan which proposes the science and technology initiatives and the LDRD Portfolio Strategy which are drawn from:

- DOE Strategy
- National Goals, policy, and regulatory frameworks
- Analysis of trends in science and technology addressing energy policies and markets
- Input from expert external advisors
- Input from Alliance Board
- NREL Research Council and its core capabilities

The overall NREL LDRD program in 2017 is $14.5 M, approximately 4% of the lab's total operating budget. Table 1 below shows the distribution of LDRD projects for F16 and FY17:

For FY17, the following expenditures were made within the LDRD program:

- Director's Fellowships $ 1.3 M

- Transformational Initiatives $ 5.5 M
- Sustaining Projects $ 6.9 M
- Seed Projects $ 600K

In addition, management and administrative costs of the LDRD cost $210K for FY17

Table 1: FY16, FY17 NREL LDRD Projects

Type of LDRD Project	FY16	FY17
Transformational	22	11*
Sustaining	30	31
Seed Projects	8	10-12 (planned)
Director's PostDocs	8	12

*Additional allocations are planned in FY17

NREL's priorities for 2017 in transformational initiatives are as follows:

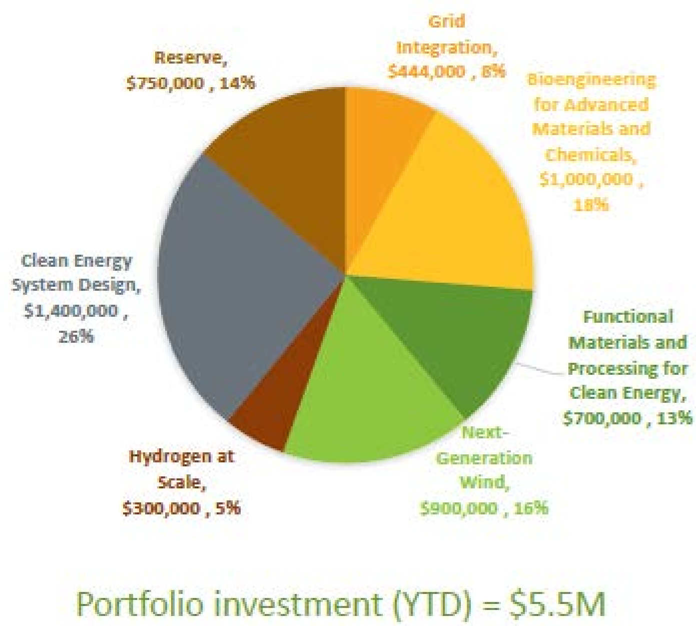


Figure 15: NREL'S Portfolio Investments

1. Functional Materials and Processing for Clean Energy. The NREL functional materials and processing initiative aims to: 1) accelerate the discovery and development of new materials, devices, processes, and tools for deployable low-cost reliable RE/EE applications and their rapid evolution into deployable technologies; and 2) accelerate the development of materials processing science to enable new, scalable, high-throughput low capital (CAPEX) manufacturing technologies.organic perovskites

2. Bioengineering for Advanced Materials and Chemistry. NREL seeks to leverage its vast experiences related to renewable fuels development to help enable this strategy which will: a) provide near-term profitability to companies in a low oil price environment, b) provide greener, lower-cost alternatives to some current chemical and material building blocks, and c) help enable renewable fuels production through co-production of fuels and products.
broadening our R&D focus beyond fuels to the exploration of intermediate molecules pertinent to the chemical and polymer industries.

3. Hydrogen at Scale. NREL seeks to build on its decadal expertise and accomplishments in hydrogen science and technology to go beyond vehicle applications to develop the needed scientific understanding and technology improvements for integrating hydrogen into the electric grid and industrial applications. By integrating capabilities in hydrogen production, storage, and utilization (the three pillars of the initiative) with systems analysis (systems, techno-economic, deployment), and energy systems integration, NREL is working to make major collaborative contributions to advancing Hydrogen at Scale.

4. Grid Integration. NREL's priorities around grid integration helped to inform and similarly reflect those described in the Department of Energy's *Quadrennial Energy Review*. Specifically, the architecture of today's grid reflects its origin nearly a century ago as a one-way delivery system connecting large, central generators to passive customers. Several factors are challenging this existing paradigm; these include the emergence of new distributed energy technologies, new threats to grid reliability and resilience, and increasing demand from consumers for new and different energy services, including the ability to generate their own energy on-site. NREL's LDRD investments in grid integration seek to address these challenges by providing groundbreaking research that reflects real-world and emerging grid conditions by leveraging the capabilities of the Energy Systems Integration Facility and collaborating with other national labs as part of the Grid Modernization Laboratory Consortium.

5. Next-Generation Wind. The goal of next-generation wind is to make unsubsidized wind energy significantly cheaper than fossil-fired generation. Further cost reductions will be achieved through research that provides the technical foundation to improve design and operation of wind plants with a goal of effectively integrating wind with new materials and processes that enable cost reductions in the wind energy manufacturing supply chain.

6. Clean Energy System Design Institute. The aim of this institute is to develop the architecture for clean energy systems design data, tools and visualizations. This initiative seeks to integrate NREL's applied science and engineering, analysis, decision science, and policy analysis capabilities. This outcome will make sophisticated tools more broadly accessible to enable more rapid transformation of clean energy systems by market participants and stakeholders.

Processes for determining funding levels at lab level (interactions with HQ, etc.)

NREL interacts with DOE HQ in the same way as every other lab to determine LDRD levels that are a compromise between NREL's desire to expand the program and tchargesmanaging overall costs of running the Lab. At present NREL spends about 4% of its annual operating budget on the LDRD program, an amount that has been gradually increasing in recent years. This puts it in the middle range of Lab LDRD costs. NREL demonstrated that they invest LDRD funds based on their Strategic Agenda and in close collaboration with DOE based on their Annual Planning processes. The core objectives of the Strategic Agenda for NREL is to

- Increase early stage research
- Recruit and retain would class scientists and engineers

- Strengthen partnerships with leading universities
- Maximize the impact of the *Energy Systems Integration Facility*

Reflected in the NREL Annual Plans are commitments to strengthen NREL core capabilities and impact and its leadership position using LDRD.

The Laboratory Level Procedure for LDRD (L-L P 4-4.1) is a controlled document, is reviewed and updated as necessary and forms the basis for the LDRD program guidelines at NREL.

Development of the LDRD call (how it relates to lab-specific goals and resource allocation between these various goals and strategies)

The NREL process for the development of the call is shown in Figure 16. This shows the multiple levels of both identifying strategic priorities and implementing those in the selection processes.

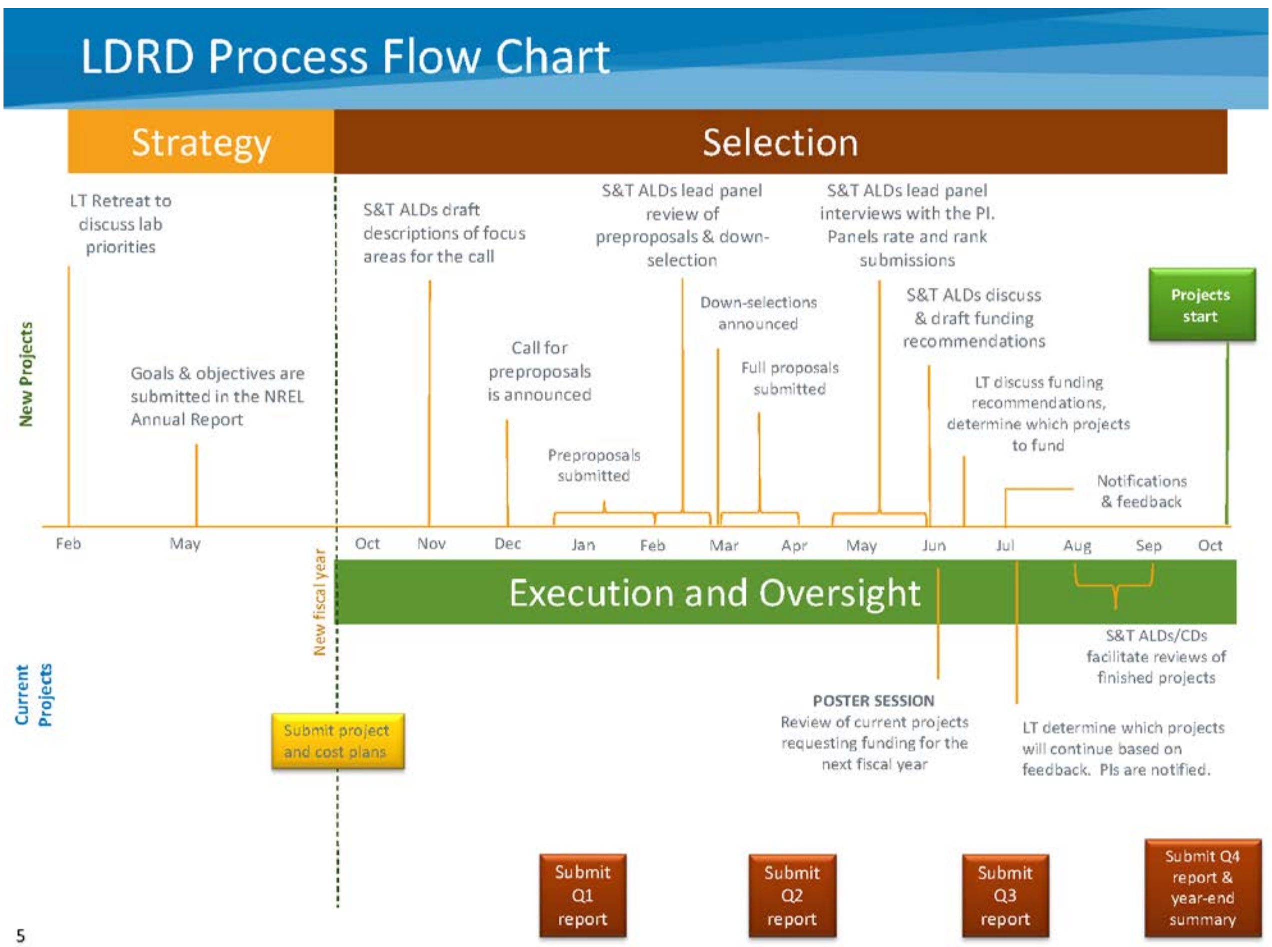


Figure 16 NREL Selection Process

In the NREL's Leadership Team (LT) Retreat. The Associate Lab Directors (ALDs) present priorities and ideas that align with the Lab's core competencies. Opportunities are highlighted in the NREL Annual Plan as transformational initiatives. The LT identify gaps in core program areas that would benefit from LDRD funding, additionally other priorities and gaps are categorized as "focus areas" and highlighted in the call for preproposals. The call for pre-proposals is announced at the end of Q1. S&T ALDs lead the review of submissions in the focus area that most applies to research in their directorate. Those same S&T ALDs establish one review panel per focus area, members include: center directors (CDs); Lab Program Managers (LPMs); Research Fellows (RFs); and additional Subject Matter Experts (SMEs).

Detailed selection processes for projects in different goals/areas (review process)

Principal investigators (PIs) with pre-proposals that rate "high" are asked to submit a full proposal on that research. If there is wide disagreement on the rating, the PI is asked to submit a full proposal and given the opportunity to defend the research in person. Feedback on pre-proposals that are not selected is informal at this stage due to the number of submissions received. Panels review pre-proposals on technical soundness, innovation, and program relevance. PIs who are selected to submit a full proposal are also scheduled for a 30-minute panel interview that includes a 15-minute presentation by the PI or team member and 15 minutes for questions from the panel. This review by panel, includes two external reviewers (university, industry and other strategic partners) and internal reviewers who reviewed the pre-proposals. Panels rate the full proposals and presentations against the following criteria:

Uniqueness (30%)	The degree to which this proposal is new, revolutionary or disruptive and provides a new capability/competitive advantage which could put NREL in a leadership position in this technical area.
Relevance/Impact (35%)	The significance of the proposed research, it's potential to contribute to NREL and DOE goals, and the probability of follow-on support by the DOE programs.
Quality of the Proposal (20%)	The level of technical soundness of the project plan and approach, and the appropriateness of the resource request.
Team Strength (15%)	The degree to which the PI has assembled an appropriate, capable, and complete set of personnel; the adequacy of the facilities and equipment intended to be used. The level of activities and teams across disciplines within a center, across centers within the Lab, among National Labs and universities.

ALD panel leaders meet to discuss the top proposals in each of the categories and will identify specific proposals that will be recommended for funding in the next fiscal year, proposals should be considered for the transformational initiatives as well as proposals that could benefit from seed funding to boost their chances for other funding opportunities, and Identify additional funding opportunities beyond the LDRD program for proposals that are worthy but do not qualify for LDRD.

In the area of the Director's fellowship program the aim is to attract the next generation of exceptional recent PhD graduates with outstanding talent and credentials in renewable energy research and related disciplines. The procedure followed is that a candidate creates a proposal with the guidance of a mentor. The Research Council peer reviews candidates' proposals and down-select for interviews. Top candidates are interviewed by a panel of the Research Council, Lab program managers and selected subject matter experts. Candidates are rated and ranked using the same process as the review of sustaining proposals however the criteria includes the number of publications each candidate has. The NREL Research Council submits a list of recommended top candidates to the S&T deputy director, who ultimately determines and approves the final selections. Director's Fellows receive two years of LDRD funding and a third year of support from the center they reside in and publish on average 3 peer reviewed publications a year.

Seed projects are short-duration (within the fiscal year) projects that provide initial data or proof-of-concept on ideas that will be proposed in FOAs or directly through the upcoming planning cycle or as part of ongoing active program management. These projects potentially establish the foundation for proposing a transformational or sustaining LDRD project in the next funding year.

Processes for Evaluating Impact

In the overall review of projects the role of S&T ALDs and center directors is to evaluate project progress and impact via face-to-face meetings and quarterly reports. Projects are reviewed at the annual poster session which is scheduled in conjunction with the S&T Committee meeting, discusses accomplishments and next steps and is used to determine which current projects will be funded in the next fiscal year; feedback is provided to the program administratorto be compiled and forwarded to the Leadership Team for review The impact from projects in the form of future funding, patent applications, patents, and present and forthcoming publications is monitored throughout the lifecycle of the project and an additional three years after LDRD funding has ceased. The impact at the individual investigator level is done through the usual performance reviews and feedback.

Overall the DOE Golden Field Office is responsible for ensuring that the LDRD projects adhere to both the rules and the spirit of LDRD and that the research is in the DOE Mission space. As part of the annual reporting process NREL reports to DOE HQ what has resulted from the LDRD projects in the form of a yearly report. This report provides a summary of the projects, including a section explain the significance of these projects to DOE. For example, in 2016 LDRD projects at NREL resulted in: 79 Publications; 2 Patent Applications; 5 Provisional Patents; 15 Record of Inventions; 3 Developed Tools/Software and greater than $6 Million in follow on DOE funding over 3 years.

High-level overall impact of LDRD at the Lab (including self-studies):

In general, LDRD projects are successful and impactful in both direct (see below) and more systemic ways including mentoring and project management training for post-docs and early career researchers; the internal support systems in NREL including remote sensing, user facilities, and the focus and emphasis on collaborations with industry, directly impacting economic development.

The NREL LDRD programs are assessed for long term impact in a variety of ways including:

(i) Impacts of LDRD in Renewable Fuels and BioSciences
  - Mapping Algal Network Signaling to Enhanced Fuel Production: (1) enables hypothesis-driven strain-engineering strategies targeting active accumulation during active growth; (2) data generated here has informed strain-engineering strategies in oleaginous platform biocatalysts, effectively enhancing HC productivity.
  - Dimethyl Ether (DME) Catalysis to Hydrocarbon Fuels: (1) high value gasoline blendstock (octane >100) with high energy density and low aromatics; (2) leverages commercial DME production routes and agnostic to DME source; (3) demonstrated route to renewable jet fuel development.
  - Nanocellulose as a polymer precursor: (1) offers an enzymatic strategy towards nanocellulose isolation; (2) intriguing material properties (e.g. polyethylene properties when dry but totally water soluble).
  - Bio-based Materials Utilizing Biology/Catalysis: (1) new bio-based polymers that can serve as functional replacements for the current suite; (2) demonstrating value of a hybrid biology/catalysis approach to material synthesis.
  - Lignin Utilization: (1) can significantly improve the economics of finished fuel; (2) can significantly improve life cycle cost of process (depends on product choice).

(ii) Grid Modernization/Energy System Integration: Grid Modernization NREL's multi-directorate LDRD investments in grid modernization have helped lay the framework for research questions on needed future grid technologies and cybersecurity challenges that may occur from an increasingly connected and distributed power grid. Specifically, they demonstrated foundational work that helped NREL develop expertise around distributed control systems, as well as predictive operational and production requirements toward grid design architectures by developing tools and methodologies to address emerging issues in the power sector. As part of these efforts, NREL hired Erfan Ibrahim as director of Cyber Physical Systems Security and Resilience to emphasize the importance of cybersecurity in a more complex electric grid. This work, and similar LDRD work at other National Labs, helped create the foundation for the Department of Energy's $220 million Grid Modernization Laboratory Consortium, which was established as "a comprehensive effort to help shape the future of our nation's grid and solve the challenges of integrating conventional and renewable sources with energy storage and smart buildings, while ensuring that the grid is resilient and secure to withstand growing cybersecurity and climate challenges." In summary, the research showed (1) distributed controls to optimize millions of distributer power devices; demonstrate a locational marginal price (D-LMP) framework in the ESIF at NREL; and (3) real-time grid forecasting.

Detailed examples of processes through posters and deep dive into selected projects

Deep Dive LDRD Projects:

- Bioscience & Renewable Fuels, Chemicals: Lignin Utilization
- Advanced Materials: Perovskite S&T
- Engineering Technology: Improving Accuracy of Lidar-Based Turbulence Measurements
- Grid Modernization: Distributed Control for Energy Systems
- Clean Energy Systems/Decision: Power Sector Modeling

An outstanding example of the impact of LDRD investment in Perovskite Research where NREL's capabilities in perovskite research have expanded through the cyclic-interconnected nature of multiple complementary funding sources. NREL's historical Basic Energy Sciences (BES) program in Solar Photo Chemistry (SPC) identified the need for a capability to understand perovskites at a fundamental level which led to a FY 2013 LDRD project in high-performance, solid-state perovskite-based solar cells ($500,000 over two years). The results of this two-year LDRD award led to three EERE SunShot awards totaling nearly $2.4 million over four years, and a technical service agreement (TSA) funded at more than $250,000/year (ongoing since 2014). The results of this work enabled researchers to realize/identify a need and opportunity for building a new capability in understanding crystallization of this class of materials, which led to a joint SLAC National Accelerator Laboratory/NREL LDRD project in FY 2015 (nearly $500,000 over two years) entitled "Crystallographic feedback for low-defect hybrid organic/inorganic perovskite films as PV absorbers" understanding film formation and (nanocrystal) phase behavior that now inform the understanding of fundamental stability issues and how to scale the processes to roll-to-roll processing. Between FY 2016 and FY 2017, four additional LDRD awards (2 director's fellowships, 2 project LDRDs) were made to expand NREL's capabilities in these areas, which were based on results from both prior LDRD and SunShot awards (novel device structure) and informative capability needs from the BES SPC (quantum computing). The LDRD investments and subsequent work have propelled NREL to become the top publishing and highest impact US institution (as measured by institutional h-index) in this field with more than 86 peer-review papers many from Nature and Science journals (6 Nature Comm, 1 Nat. Phot., 1 Nat. Energy, and 1 in Science). This highly collaborative program led to $8.6M of new DOE and commercial funding with another $5M BES Materials proposal currently being developed. The program allowed recruitment of several very high quality postdocs through Director's fellowship and EERE fellow programs, had strong commercial interest and actual investment and led directly to 8 patent apps and 6 patent apps in follow-on funded work.

Posters: Eighteen posters were made available across all categories of LDRD funding categories. Most of the projects were recently completed. The posters were explained by PIs and often post-doctoral fellows of NREL. Several included collaborations with universities, and with corporate partners. The posters presenters indicated the importance of LDRD in either bringing them to NREL or in enabling them to undertake new activities outside the range of existing programs that would lead to further funding. Regarding this latter point, 12 out of the 18 posters had follow-on funding that totaled approximately $20M. All the posters had a healthy level of publications and/or records of invention or patents.

Directors Fellows: The fellows program was established in 2011, the first director's fellowship started October 2012. To date, 15 postdocs have come to NREL via this program; 3-4 additional starting in FY 2017, 1-2 additional starting in FY 2018. In FY 2016, the Director's Fellowship was upgraded to include a "Nozik Fellowship", named after NREL Fellow Emeritus, Art Nozik, and is given to one outstanding post doc. Figure 17 shows the destinations of the fellows. Over 50% of the fellows stay at NREL or other DOE labs, the remainder going to academic positions.

Figure 17: Destinations of NREL Fellows

Key observations from the visit

- NREL is uniquely situated between the DOE, academic and other research organizations and industry, NREL envisions itself in the "gap" between discovery science research and commercial-ready technologies in energy, especially in renewable energies.
- There is very clear strategic involvement and leadership of LDRD from senior NREL management in a way that benefits both LDRD and NREL.
- At every level from post-doctoral fellows through to senior management there was a very clear view of the importance of LDRD to the Lab's mission, ranging from the research undertaken through to the role of LDRD in recruiting, maintaining and reinvigorating the workforce.
- NREL has a very clear and transparent way of representing the impact of its work to DOE, to business and to the science engineering and broader communities.
- Individual processes at NREL regarding LDRD operate on multiple levels with checks balances and feedback at every stage. The processes are well-managed and appropriate.
- The impact of individual projects is well understood. LDRD plays a vital role in moving NREL forward in a way that anticipates and instigates future programmatic needs while simultaneously ensuring that the highly-trained workforce for those needs is in place.
- NREL researchers are highly collaborative with federal entities and especially industry; this allows them to identify gaps in commercial practice and fill gaps through strategic research.
- User facilities are variable and being upgraded to incorporate not only electric grid but thermal, fuels and water infrastructure for testing and optimization.

- The changes in approach that have been implemented in the last 24 months of NREL have increased their intellectual property output which is enhancing the existing revenue stream from licensing and royalties.
- It may be beneficial to enable others to quickly understand the impact that the Subcommittee saw through a simple monitoring system that links different generations of projects and publications and so allows the overall impact of the program to be easily understood in a way that is not presently possible in any institutions that the panel is aware of.
- Overall the LDRD program appears to be very well and carefully run and monitored both in the intended spirit and in the detail of the congressional charge of the program of the program and in a way that couples innovation at the Lab and scientist level with the anticipated future DOE, industry and general science and engineering needs.

Appendix E - References

Commission to Review the Effectiveness of the National Energy Laboratories. (2015). *Securing America's Future: Realizing the Potential of the DOE National Laboratories, Volumes 1 and 2.* U.S. Dept. of Energy.

DOE Office of Inspector General. (2014). *Audit Report: OAS-L-15-04.* U.S. Dept. Energy.

GAO-01-927. (2001). *Better Performance Reporting Could Aid Oversight of Laboratory-Directed R&D Program.* Govt.

GAO-04-489. (2004). *Federal Research: Information on DOE's Laboratory-Directed R&D Program.*

GAO-16-486R. (2016). *Information on DOE's Laboratory-Directed Research and Development Program.*